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# Performance and Benefits of Architectural Coatings on 21st Century Façades


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## Abstract

*Skyscraper cities, while conceptually rooted in mid-20th century architecture, are being reinvented to appeal to a new generation – and a new market. The iconic glass and metal curtain wall, however, continues to epitomize upscale, modern construction. It is imperative that these wall systems be technologically sufficient to meet contemporary standards of durability. Secondary components of the system, such as finishes, must be carefully considered. By understanding the third party organizations that certify architectural coatings, and by specifying the correct coating for each skyscraper's individual situation, the service life of the entire structure can be optimized.*



**Keywords: aluminum, anodization, architectural coatings, fluoropolymer, weatherability**


Vertical cities – businesses, services and residences that occupy a single tall building -- are not a new concept. What is new is the number of skyscraper cities now being built and their success in the marketplace.

In the post-WWII era, European tower blocks designed by well-known architects of the modern movement provided inspiration for mid- and high-rise buildings across the globe. But because these towers lacked economic diversity, and were often poorly constructed, most suffered a rapid demise (Bradbury 2014). A few of these prototypes did endure, or even flourish, and they provide valuable lessons regarding what kind of amenities contribute to the longevity and success of a residential high-rise. Social and economic diversity are imperative, as is ample green space.

Another notable factor in the success of contemporary skyscrapers is their ability to tap into the "experience economy," in which unique, place-based experiences attract people (Pratt 2009). When buildings become settings for such experiences, their aesthetics take on a new level of significance. Building envelope design and materials are the key to a structure's artistic expression and can translate into its commercial and critical success. One building element that has been retained from high modernism to fulfill this purpose is the "curtain wall," a thin, typically aluminum-framed system with infill panels that are usually made of glass. With their lightness and flexibility, these non-loadbearing exterior walls not only provide the practical benefit of allowing more usable square footage within a building, but also epitomize upscale, modern construction.

Figure 1. PVDF liquid coating on the Union Properties Tower in Dubai, United Arab Emirates (Source: AkzoNobel)

## Bringing Curtain Walls into the 21st Century

Any aesthetic or functional deterioration of the curtain wall risks shortening the life span of a building or creating the need for extensive repairs. The extent of building surface area involved in high-rise architecture can make repair and refurbishment cost-prohibitive and can potentially involve liability. Even the appearance of building envelope degradation can reduce the success of a structure in the marketplace. Furthermore, creating a durable curtain wall is important to the overall sustainability of a structure.

The main components of a typical curtain wall -- glass and aluminum -- have long service lives and can be expected to last throughout the life of the main (structural) building materials. However, the overall system could be compromised by sub-optimal performance of its other constituents. This means that considerations such as the building finish become crucial. For monumental projects, designers should not gamble by using anything less than coatings that meet the highest standards, as defined by third-party organizations. Additional considerations, such as environmental concerns, ease of use and color requirements, should be carefully weighed during the design process so that a client's needs could be met and the long-term success of the skyscraper can be ensured.

## How is a Product's Performance Determined?

Two main quality organizations addressing the fenestration industry exist worldwide:

- The American Architectural Manufacturers Association (AAMA), based in the United States and used in North America and worldwide.
- Qualicoat, based in Switzerland and used extensively throughout Europe, with a growing user base in Asia and Latin America.

Both organizations recognize three levels of performance, often referred to as standard-, super- and hyper-durable. There are also smaller regional organizations such as GSB (with a focus on Germany) and GB (located in China).

### AAMA

Standards established by the national trade association AAMA are voluntary and include specifications, performance requirements and testing procedures for pigmented organic coatings on aluminum extrusions and panels (for factory-applied organic coatings only). As defined by the AAMA:

- AAMA 2603 identifies pigmented organic coatings that will provide a good level of performance, highlighted by one year of 45 degree South Florida weathering.
- AAMA 2604 focuses on high performance organic coatings that will provide and maintain a high level of performance that requires five years of South Florida weathering.
- AAMA 2605 focuses on organic coatings that will provide and maintain a superior level of performance that requires a 10 year South Florida exposure.

Coatings meeting the AAMA 2605 standard are appropriate for use on high-end building exteriors and are expected to last the lifetime of the building.

### Qualicoat

Qualicoat licenses plants and issues a quality label that ensures finished coated aluminum products meet the organization's technical specifications. Their stated mission is to establish, and continually improve technical specifications; grant licenses to coating plants that apply for the quality label and monitor their application processes; and test and approve chemicals and coating products.

As defined by Qualicoat:

- Class 1 coatings are subjected to Florida exposure facing five degrees south for one year.
- Class1.5 coatings are subjected to Florida exposure facing five degrees

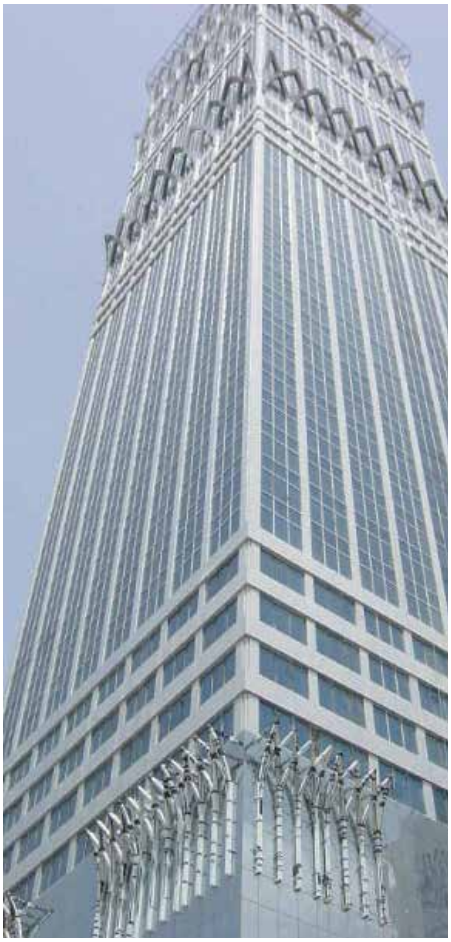

Figure 2. PVDF liquid coating on the Sheraton Shenzhen Futian Hotel located at International Exchange Square in Shenzhen, China (Source: AkzoNobel)

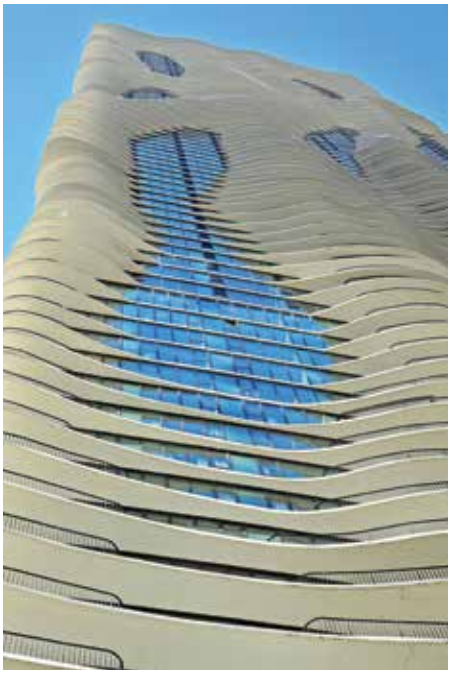

Figure 3. PVDF liquid exterior coating on the Aqua Tower in downtown Chicago. Designed by Jeanne Gang, Aqua is the tallest built skyscraper to be designed by a female architect (Source: AkzoNobel)

Figure 4. PVDF liquid exterior coating on the Hess Tower in Houston, Texas (Source: AkzoNobel)

Figure 5. PVDF liquid exterior coating on Alabama's tallest building, the RSA Battle House Tower located in Mobile, Alabama (Source: AkzoNobel)

south for two years with an annual evaluation.

- Class 2 coatings are subjected to Florida exposure facing five degrees south for three years with an annual evaluation.
- Class 3 coatings are subjected to Florida exposure facing 45 degrees south for 10 years.

## Testing Procedures

Procedures for testing architectural coatings include both mechanical tests – for example, the application of loads or abrasive forces – and exposure testing. Some issues, such as coverage, fall within the purview of quality control and are therefore NOT within the scope of performance testing.

Tests may include:

- Impact resistance
- Adhesion
- Humidity resistance
- Mortar resistance
- Acid resistance, and/or
- Pencil hardness…

….But the most significant factor influencing a coating's performance is its weatherability, particularly its UV resistance.

Tests that are specific to weatherability measure a coating's

- color retention,
- chalk resistance,
- gloss retention, and
- erosion resistance.

Laboratory tests of painted panels, conducted within cabinets using an artificial light source to simulate sunlight, can provide some measure of a coating's UV resistance. Qualicoat gives coatings a provisional approval when they meet artificial test criteria such as UV testing. The most complete results, however, are obtained in natural environments that provide exposure to the full spectrum of light in combination with other factors such as condensation, biological growth and physical erosion that are not recreated in a laboratory cabinet.

Data from weather testing performed in Southern Florida is considered to be the global 'gold standard' of testing data. The subtropical climate in that region provides natural, realistic exposure to product specimens, yet results can be achieved on an accelerated timeline because one year of Florida's sunshine and moisture can equate to several years of exposure on other parts of the globe and the 45 degree south facing exposure also makes the exposure more severe. The state offers high annual UV, high year-round temperatures, abundant rainfall and very high humidity. Southern Florida exposure data are mandatory by Qualicoat, AAMA and GSB.

AAMA 2603 specifies that weathering testing involve exposing "six samples representing typical products on an exposure rack for one year in Southern Florida at a 45 degree angle facing south… [The] exposure site should be inland at least 3.2 km." AAMA 2604 further specifies that Florida exposure must be south of latitude 27 degrees North and that the panel must be in position for a minimum of five years; AAMA 2605 requires the same latitude and specifies that the panel must be in position for a minimum of 10 years.

Florida is home to the largest outdoor weathering testing facility in the world. A variety of specimen mounting and exposure techniques are used to obtain accurate results; tests on exterior-use coatings are conducted using direct exposure. Test panels are mounted so as to directly face the sun, with varying angles and mounting techniques.

Coatings manufacturers typically work directly with a testing lab, conducting a series of tests that will provide the most complete set

Figure 6. The Shard is a 95-story powder coated skyscraper in Southwark, London (Source: AkzoNobel)

of data for a given product. Specimens are typically sent to the testing lab directly from the manufacturer's R&D group; the testing lab then conducts the exposures and issues progress reports to the manufacturer. All testing is "blind" so there is no bias in the data from the testing lab. Manufacturers then provide customers with the test data.

In an effort to collect more data – and collect it faster – testing facilities are branching into different locations and different types of testing. Exposure facilities in the Arizona desert offer about 20 percent more sunlight, higher annual temperatures, and lower humidity than is typical in Florida. The increased UV and the extreme dry heat make Arizona the ideal location for testing highly durable materials that are intended for use in desert areas around the world.

The testing facilities further accelerate the weathering process by using "concentrators" with an array of mirrors to reflect and concentrate full spectrum sunlight onto test specimens. The concentrators are capable of tracking the sun throughout the day in both azimuth and elevation. The combination of mirrors and tracking maximizes the amount of UV exposure that a test specimen receives. These accelerated natural weathering devices can quickly produce extremely useful data concerning the durability of highly durable products. Depending on the product being tested, companies can specify "misting" to simulate rainfall or morning dew.

Figure 7. The Emirates Park Hotel, in Dubai, United Arab Emirates is powder coated (Source: AkzoNobel)

Again, this is for the purpose of simulating real world installations.

## Liquid and Powder Coatings vs. Anodization: Which Perform Best?

An expanding array of coatings options – both powder applied and liquid applied -- can lead to confusion regarding which ones will comply with a given standard. Compounding the confusion is an erroneous belief that powder applied coatings are chemically different than liquid applied coatings. All paints, regardless of whether they are liquid or powder, are comprised of two principal ingredients: resin and pigment. Liquid paint has solvents that act as a vehicle to deliver the resin and pigment to the substrate. Powder coatings are applied in a finely ground form, without the use of solvents.

It is the resin that provides the film with mechanical characteristics, such as gloss and gloss-retention, as well as resistance to chalking, abrasion, scratching and dirt accumulation. Pigments provide the color of the painted surface, and are responsible for any color change or fading as they degrade over time. Regardless of whether a coating is applied as a liquid or powder, as long as the resin and pigment chemistry is comparable, the finish will meet the same weathering criteria.

Coating longevity is best achieved by combining high quality ceramic pigments with UV transparent fluoropolymer resins (resins that don't absorb light energy). Fluoropolymers are fluorocarbon-based polymers with strong carbon-fluorine bonds, and the category includes polyvinylidene fluoride (PVDF), sometimes referred to as PVF2, and fluoroethylene vinyl ether (FEVE) sometimes referred to PVF3. Fluoropolymer coatings are commonly referred to as "new generation" coatings. First discovered by accident by a DuPont chemist in the 1930s, these polymers were found to be highly resistant to corrosion and chemically very stable. Coatings (powder or liquid) with a high level of fluoropolymer typically have better weathering performance than conventional coatings.

Of the resin types most commonly used to coat aluminum substrates:

- Conventional acrylic and high solids polyester liquid coatings, as well as standard durable polyester powder coatings, will meet AAMA 2603 requirements.
- Silicone polyester and 50 percent polyvinylidene fluoride (PVDF) liquid coatings, as well as super-durable polyester powder coatings, will meet the requirements of AAMA 2604.
- Seventy percent PVDF liquid coatings and hyper-durable fluoropolymer powder coatings will fulfill requirements for AAMA 2605.

Figure 8. The Marriott Hotel, in Almaty, Kazakhstan is powder coated (Source: AkzoNobel)

Seventy percent PVDF liquid coatings and hyper-durable fluoropolymer powder coatings are therefore the best choices for use on contemporary skyscrapers.

Anodized metal is really not 'coated' in the usual sense; its surface has been chemically converted. Aluminum naturally develops a thin oxide layer and anodizing increases this aluminum oxide layer by electrochemical means. The anodic film of aluminum oxide then acts as a protective layer.
Anodizing, besides an old technology, is still a popular option. It results in an extremely abrasion resistant finish with an attractive metallic sheen (as the metal is visible through the film). However, there are some limitations involved:

- There are fewer color options associated with anodization.
- Color consistency is more of a challenge.
- Changes in the orientation of the metal result in differences in

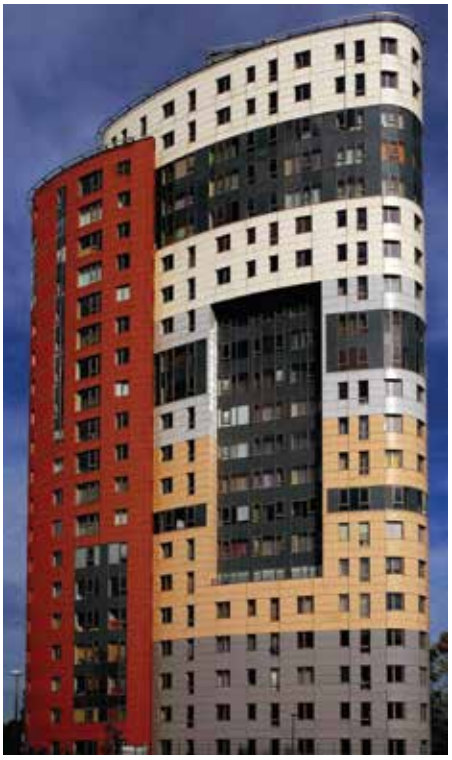

Figure 9. The Solaris Building is powder coated (Source: AkzoNobel)

Figure 10. The Eureka Tower is a powder coated 975-foot skyscraper located in the Southbank precinct of Melbourne, Victoria (Source: AkzoNobel)

appearance. For example, horizontal and vertical window mullions made of anodized aluminum will not be uniform in appearance.

- Damaged surfaces cannot be repaired.
- Anodizing can only be applied to aluminum, while coatings are more tolerant to different substrates.

Currently, anodizing represents 30 percent of the North American market, largely because it is a less expensive alternative than PVDF coatings.

**Environmental Considerations**

There has been a shift in the coatings industry toward using powder applied coatings, primarily driven by companies' desire to move away from products with VOCs. Powder coating is typically a one-coat process, which brings a great deal of efficiency to the application. In addition, a well operated application line could reduce waste below 1 percent.
Both powder and liquid coated extrusions must be cured by baking, a process that requires temperatures of 450 degrees F in order to heat the substrate to the necessary peak temperature. It is during the baking process that the solvents – and VOCs – in liquid paint escape into the environment. But there has been a great deal of investment in pollution control for liquid-applied coatings. Nearly all commercial applicators use VOC abatement systems, which capture over 98 percent of VOC emissions from the liquid paint line and send them to a regenerative thermal oxidizer (RTO), where the VOCs are destroyed. An added benefit is that the heat from this process is captured and utilized for curing, which helps to lower the amount of carbon fuels required to cure the surface. There is, however, an increase in carbon dioxide emissions resulting from the use of carbon-based fuels to power the RTO. In the United States, net carbon dioxide emissions are slightly greater when using liquid-applied paints.

Because it is a no-VOC process, anodizing is sometimes perceived as being environmentally friendly. But the amount of electricity required for the process – which entails immersing aluminum parts in an acid electrolyte bath and electrically charging them – is typically generated by carbon fuels, which means that the carbon footprint for anodizing is actually quite high. The anodizing process is also water intensive, using millions of gallons a year, and it involves the use of corrosive acids and chemicals.

**Color Considerations**

One benefit of liquid paint is that it comes in a wide range of color choices. Where custom colors are desired, because most custom liquid colors are mixed in the factory, the cost is typically the same as for a standard color. Custom colors can also be created with liquid paint simply by mixing it in numerous individual batches at the coater's site, making it suitable for Just-In-Time production. Furthermore, in the commercial architectural market, a large percentage of the finishes specified are bright mica metallic silvers and bronzes, and liquid paint holds metallic flake very well. Liquid paints offer low to medium gloss availability.

Powder coatings are also available in a wide range of colors, and are increasingly able to include brighter smooth metallics in different performance levels. Powders offer a wide range of gloss choices, although they cannot be blended to create new colors.

New developments in curtain wall construction are helping increase design flexibility while reducing costs. Curtain wall manufacturers are using polyamide to establish a thermal break, which completely separates the two sides of the aluminum profile. Having this separation allows the interior profile to be coated independently from the exterior profile, resulting in more color options for a building's interior locations. Furthermore, the separation of the inside and outside aluminum profiles allows designers to use ultra-durable fluoropolymer coatings (those meeting the AAMA 2605 standard) only on the exterior of the structure, while choosing a more suitable and lower cost, paint for the interior.
A major drawback to anodizing is that variations in the metal will cause color differences that are apparent in the finished surfaces. Paints, whether liquid or powder, eliminate this variation. Anodized metal, when installed on horizontal and vertical surfaces, will reflect light differently, causing the colors to appear different. A metallic paint on those same surfaces will appear to have some color difference, but significantly less than an anodized finish. Anodized surfaces are also susceptible to chemical change and damage as the result of coming into contact with mortar. This can be a major problem on the jobsite, especially in curtain wall projects that have masonry work near them. Once an anodized surface is damaged by mortar, there is no way to repair it other than to completely replace the damaged parts. Neither liquid nor powder paint is susceptible to mortar damage.

Scratches or other installation damage cannot be repaired on an anodized material, whereas liquid coatings can be used to match the original color of a coated material and can be used for field touch-ups on powder- or liquid coated substrates. Furthermore, anodizing aluminum that has a high recycled content can result in a mottled appearance.

Using coatings to cover unsightly recycled aluminum surfaces represents a significant environmental advantage of coatings in comparison to anodized substrates, considering that recycled aluminum requires only 5 percent of the energy needed to produce virgin aluminum. Furthermore, aluminum does not lose strength or otherwise degrade during repeated recycling – about 80 percent of all aluminum ever produced is still in service – so reusing aluminum confers an economic benefit as well.

The use of liquid or powder coatings has another advantage over the natural metallic appearance that is inherent with the use of anodized aluminum: color is becoming increasingly important in marketing. As is evident with retail branding, the bright, saturated colors that are possible with organic pigment make products, signage and building cladding highly recognizable. Skyscrapers that are targeting a high-end customer base can leverage this power of branding, as well.

## Coatings Application

A common perception is that the cost savings for liquid is associated with a savings in materials: liquid paint can be applied at lower film levels – about half, on average, the film thickness of powder. However, powder application may result in a more efficient use of materials. Aluminum extrusions are coated in specially designed spray booths, where over-sprayed powder can be collected, recycled and reused. This reclaiming process can make use of nearly 99 percent of the powder coating material, resulting in a product usage that is more efficient than liquids. And the solid material costs less to ship and store for powder because liquid paints have 30–50 percent by volume of solvent. In actuality, the total production cost for each application method is almost identical, because the stated cost for a powder coating is for a single coat but at a higher film thickness, while the stated cost of a liquid coating is at a lower film and typically includes a primer.

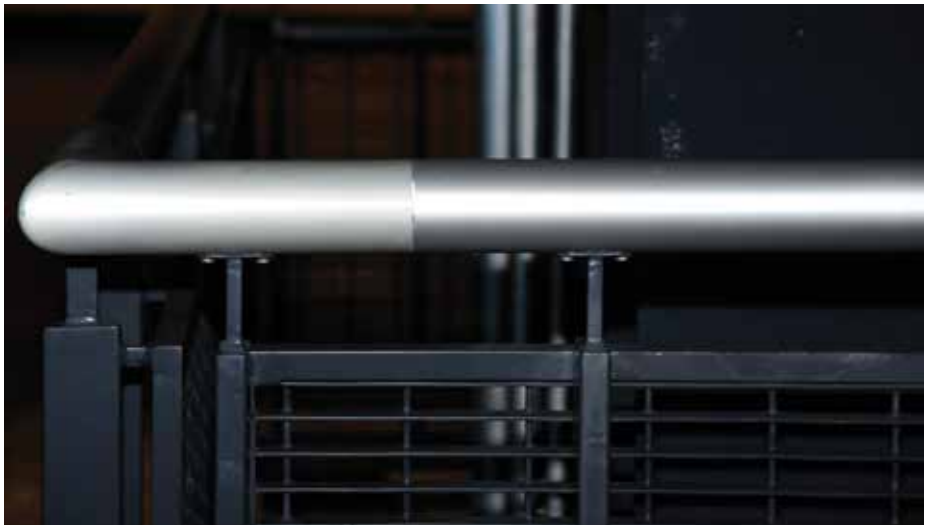

Figure 11. Naturally occurring color variations in newly installed anodized aluminum (Source: AkzoNobel)

The fact that liquid paint can be mixed in the field results in short lead times – as little as a few hours. These coatings can also be intermixed in the applicators at the factory, allowing for fast turnaround times. Powder lead times are longer for colors that are not included in a manufacturer's standard color offerings. Orders must be placed with the factory and additional time must be allowed for shipping.

The use of a powder coating results in very reliable product offerings. The single coat application achieves a uniform finish without runs, drips, sags or bubbles and finished claddings are of a superior consistency. Both liquid and powder coatings can match metallic paints well; very bright metallics will be better matched with liquid paint. Either system can be touched up by using a VOC compliant waterborne fluoropolymer system. Some liquid paints can be touched up or repainted in the field, which is a major advantage when repairs become necessary. Liquid paints containing PVDF resin types are softer paints and are not as scratch or abrasion resistant compared to other paint systems. Powder offers superior abrasion resistance. Both coating types have the ability to bend and yield with the substrate, with liquid being slightly more flexible due to its lower film thickness.
Both powder and liquid AAMA 2605 coatings come with multi-year warranties on weathering performance (including color retention, gloss and chalking) and require minimal maintenance.

Evolving coatings options, with state-of-the-art chemical compositions, are helping architectural finishes meet the service life expectations of the contemporary skyscraper. With population growth and interest in urban density and vertical living at an all-time high, this development comes just in time to ensure that the skyscrapers of the 21st century outperform their 20th century predecessors. For designers, the key to a successful outcome when specifying a coating is to consider the curtain wall substrate material, the end use of the building, and coating performance requirements. The method used to apply a coating is not as important as its resin and pigment chemistry when it comes to product suitability. For all paints, selecting the right resin combination (to protect against chalking and abrasion) along with the right durable pigment combination (to protect against fading) will give a long lasting, high performance finish.

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