#26 ToolKit

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National Coil Coating Association

Factors Influencing the Long-Term Performance of PrePainted Metal Buildings

Introduction

Most metal buildings are made with prepainted metal building panels. The coil coating process used to make prepainted metal provides many benefits, including superior bonding of paint to metal, durability, environmental friendliness, etc. As a result of the use of prepainted metal, metal buildings are aesthetically pleasing, durable, long-lasting, and economically-efficient structures.

The long-term performance of metal building panels and metal buildings is influenced by three principal factors:

1.) The choice of materials
2.) The environment in which the products are placed
3.) The variability of processes

For this document, the term "long-term performance" is limited to those aesthetic properties that the casual observer will witness as a building ages. Of course, the roof should not leak, and a strong storm should not damage the building, but these are structural and construction issues that are beyond the scope of this document. The items that are in-scope are those features that are easily seen: the presence of corrosion, delamination of the coating, the chalky appearance of a coating, color fading, environmental staining, and noticeable cracking in the fabricated areas.

Choice of Materials

Of the three factors mentioned above, selection of materials has the greatest influence on long-term performance. These materials include the aluminum or steel substrate, metallic coating (for steel), the type of pretreatment used to prepare the substrate for coil coating, and the chemistry of the primer and topcoat.

The mechanical properties of a metal building panel depend entirely on the properties of the metallic-coated steel or aluminum chosen. Guidelines for this selection process can be found in:

- ASTM *B209-14 Standard Specification for Aluminum and Aluminum–Alloy Sheet and Plate.*
- ASTM *A653/A653M Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*
- ASTM *A755/A755M Standard Specification for Steel Sheet, Metallic Coated by the Hot-Dip Process for Exterior Exposed Building Products*
- ASTM *A792/A792M-10(2015) Standard Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process*
- ASTM *A875/A875M-13 Standard Specification for Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process*
- ASTM *A1046/A1046M-14 Standard Specification for Steel Sheet, Zinc-Aluminum-Magnesium Alloy-Coated by the Hot-Dip Process*

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In addition to the mechanical properties, the metal substrate also plays a principal role in the corrosion resistance of building panels. Aluminum is inherently resistant to corrosion, except where exposed to aggressive alkaline conditions. For a steel substrate, the application of the metallic coating is a well-developed method of protecting the base, steel substrate, which is susceptible to corrosion. Metallic coatings protect the base steel and any bare, cut edges from corrosion through galvanic (cathodic) protection, where the steel is protected by the sacrificial corrosion of the zinc coating (*i.e.,* the cold-rolled steel base metal would corrode on its own, but the zinc-containing metallic coating will preferentially corrode, protecting the steel substrate).

Cleaning and pretreating the substrate prior to painting are important process steps that provide adequate adhesion of the paint system to the substrate, thereby influencing the long-term performance of metal building panels. Since the coatings are expected to remain intact and adhered to the substrate for decades, these steps in the process are critical.

In addition to providing barrier properties to the substrate, the paint layers establish the weathering performance of building panels (color and gloss retention, and resistance to chalking and environmental staining). The choice of primer and topcoat is crucial for the following reasons:

1.) The primer—along with the substrate and pretreatment—contributes to the corrosion resistant properties of the substrate's cut edges and provides adhesion between the substrate/pretreatment and the topcoat. Since nearly all building panels receive some form of fabrication, the primer adhesion to the substrate, and the topcoat adhesion to the primer, must be optimized to overcome the forces associated with fabrication.

2.) The topcoat must be properly formulated for the lifetime in the environment in which it will reside. In the case of metal buildings, the most demanding application is roofing, where a panel facing the sun with insulation underneath gets very hot, which accelerates UV-related degradation, which results in a greater degree of color fading and chalking. The primary components of a topcoat that influence long-term durability of the color and film integrity are resin choice, crosslinker choice and level, and pigment choice and level. An excellent resin system can be considerably compromised by a poor pigment choice, and the reverse is also applicable. Describing the complexities of topcoat formulation is beyond the scope of this article; however, NCCA Tool Kit #8, *Coil Coating Topcoat Systems*, offers guidance.

Environment

As a metal building product is placed in use, it is subjected to the rigors of the environment for the remainder of its lifetime. There is not much that one can do with the environment into which a product is placed, but the choice of building material can be—and must be—carefully considered so it can deliver satisfactory performance over the lifetime of the building. There are many aggressive conditions to consider, such as:

1) Aggressive UV Conditions—The closer one gets to the equator, the greater the annual UV dose. Routine clear skies—as opposed to routine cloudiness—regardless of location, increases the UV dose.

2) High Temperature Exposure—Sub-tropical (e.g., South Florida) and desert (e.g., Arizona) exposure are the most common examples of these conditions.

3) Aggressive Chemical Environments—This category may be subdivided into three sub-categories:

   a. Acidic environments associated with manufacturing facilities with acid effluent (coal-burning power plants, paper mills, etc.).

   b. Alkaline environments associated with animal confinement, high fertilizer usage, or wherever a building product comes in intimate contact with concrete.

   c. High-chloride/long wet-time environments associated with coastal exposure.

All of the above conditions require the specifier to carefully consider the type of metal substrate to be used, as well as pretreatment and coatings selection. Unfortunately, there is no "one size fits all" solution.

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Process Variability

Variability exists in all industrial processes, and—to a degree—this variability may affect long-term performance. In general, however, process variability is a minor factor along the coil coating supply chain. Far more important are the choices of substrate, pretreatment, and coatings (discussed above). A well controlled coating process will produce inferior product if a poor choice is made of substrate (e.g., choosing a metallic-layer thickness that is too thin, which leads to early corrosion), or if a topcoat with poor durability pigmentation is used, producing excessive chalking and color change. Although the coil coating processes are highly controlled, process variability creeps in as follows:

1.) Substrate Variability—Although steel production and the metallic coating process are tightly controlled, some variation exists. The most concerning in this category for building products is the metallic coating thickness. (Aluminum, of course, does not have this issue.) If there is an insufficient level of metallic coating, the ability to sacrificially protect the steel substrate will be compromised. For this reason, one must carefully consider the allowable *minimum* metallic layer thickness specification and align that specification with the environment in which the product will be placed into use.

2.) Cleaning and Pretreatment Variability—Cleaning and pretreatment production is subject to only very small process variability. History has shown that the use of these materials in the cleaning of the substrate and the application of pretreatment on a coil coating line are highly controlled. Although some variability in these processes exists, the cleaning and pretreatment chemistry, in combination with today's substrates and coatings, have shown a degree of robustness that minimizes most long-term performance concerns.

3.) Coatings Production Process Variability—Paint manufacturers produce their coatings in a batch process, but history has shown that there is little batch-to-batch variability due to the rigorous quality control process to which each batch is subjected. Topcoats need to provide certain physical properties (hardness, scratch resistance, etc.) as well as aesthetic properties (color and gloss). Of the two distinctly different sets of properties, controlling color and gloss is more challenging, although these aesthetic properties have little to do with the mechanical properties of the coatings.

4.) Coil coating process variability—The above coatings are applied on modern coil coating lines, and this process is well controlled. The three most important coatings parameters that require the greatest process control on a coil coating line are:

   a. Development of coating flexibility
   b. Degree of cure of the coating
   c. Dry film thickness produced during the application and curing process on a coil line.

5.) How process variability may affect long-term performance

   a. Corrosion—In the case of metallic-coated steel, if the metallic layer is thinner than the allowable minimum, there is greater likelihood that visible corrosion will develop over time. The way to minimize this possibility is to source the substrate from a reliable supplier that has an active and robust quality system.

   b. Delamination—In the coil coating industry, this problem was historically associated with coatings based on the high-performance resin polyvinylidene difluoride (PVDF) that was applied over an epoxy primer, but it is seldom an issue these days. Most of the primers used with PVDF technology are far more UV-resistant than the first-generation epoxy primers, and PVDF topcoats are generally formulated with a sufficient pigment level to have complete UV opacity at any dry film thickness $\geq$ 0.5 mils. Since the PVDF minimum topcoat thickness is usually 0.7 mils, and since the coil coating process is such a precise application technology, delamination is not much of an issue. More often, delamination is related to poor substrate cleaning, improper panel fabrication, and improper storage conditions after the metal building panel is fabricated.

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c. Chalk and Fade—These two topics are covered simultaneously since long-term chalk and fade issues stem from the same mechanism: topcoat degradation resulting from exposure to UV, accelerated by higher temperatures (especially where metal roofing is involved). Minimizing chalk and fade is mostly a function of the formulation of the topcoat.

Minor effects that may result from variability of the coil coating process are as follows:

i. Cure—If the cure of the topcoat is insufficient, the topcoat may experience environmental staining with time and may also show a great degree of chalking and fade. To verify suitability, however, the manufacturer runs a cure test—MEK rub resistance—and a test for flexibility on the coils and batches of paint as they are produced.

ii. Dry Film Thickness (DFT)—In the coil coating process, very thin films are applied at very fast speeds. Operational efficiency is the strength of the coil coating process. The measurement of dry film thickness, however, presents many challenges. There are electronic gauges that can measure DFT with acceptable precision, so long as the substrate is very smooth. However, a common building material—zinc metallic-coated steel—is not a smooth substrate. This means that standard electronic film thickness gauges cannot be used on coatings over this substrate. For these substrates, there are two devices are commonly used instead:

a) Tooke Gauge

b) DJH Boring Device

iii. Both devices make a precise angled cut through the coatings, and the film thickness is measured under magnification.

Both of these devices have precision statements that need to be factored into the routine readings upon which decisions are made. The precision of each angled cut is strongly influenced by the angle of the cutting implement—a knife's edge for the Tooke Gauge and a miniature drill bit for the DJH Boring Device. Each device's cutting instrument must be routinely checked to confirm that the cutting angle is within specification. Without this confirmation, errors in DFT measurements can result. Without a quality process to confirm the calibration of the instrument, one cannot rely on the DFT readings.

The question, however, is not about the precision of the instrument, but rather the effect on long-term performance of a coating that is produced above or below the maximum and minimum dry film thickness specification. There are many factors that influence long-term performance, and a coil coating line must balance all of them. Not only is the coating checked carefully for dry film thickness, but—because of the nature of a thin (≈0.7 mils) topcoat—the color of the topcoat changes as a function of dry film thickness.

Conclusion

Coil coated metal used for building products provides unrivaled long-term performance. The critical factors necessary to provide superior performance are to make an informed choice of the metal substrate, pretreatment, primer, and topcoat. Once these choices are made, the processes used to manufacture the metal substrate, pretreatment, and coatings, as well as the coil coating process used to produce the prepainted metal (if properly run and controlled), provide a level of consistency that sustains the performance of a metal building panel, and a metal building, for decades.

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