United States Steel

Technical Bulletin Construction:

Paint Systems Used in the Construction Market

For further assistance on the use of steel building panels or related topics, contact U. S. Steel Construction Sales

Group: U. S. Steel Construction Sales

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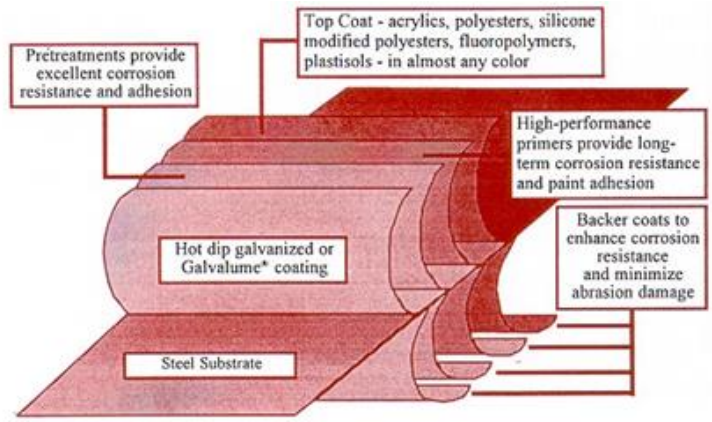
Background

The rapid expansion of the use of sheet steel in the construction market is partly due to the increased availability of high-quality paint systems that can be applied over hot-dip galvanized and GALVALUME®[1] Coated Sheet Steel products by the coil coating process. These prepainted steel products are produced under tightly controlled conditions on coil coating paint lines ensuring uniformity of the painted product and quality performance.

In the coil coating process, coils of galvanized or GALVALUME® Coated Sheet Steel are first thoroughly cleaned to provide a uniformly clean surface for the subsequent painting steps. Next, a pretreatment is applied to the coated steel surface. This is a very thin layer of chemical treatment that bonds to both the coated steel surface and to the subsequently applied paint to ensure excellent paint adhesion. A uniform layer of primer is then applied to the chemically treated surface. The primer provides flexibility to the paint system as well as corrosion resistance since it contains corrosion inhibitors. The primer is “cured” as the coil passes through a curing oven at carefully controlled temperatures. Finally, a topcoat is applied at a uniformly controlled thickness and then “cured” under controlled temperatures. The topcoat contains the color pigments as well as ingredients to provide the required gloss and resistance to ultraviolet (UV) light.

Before a paint system can be qualified for use on U. S. Steel’s products, it must undergo extensive and rigorous testing by our paint suppliers, coil coaters, and the Research and Technology Center. This Technical Bulletin discusses the types of paint systems available to the construction market and some of the performance issues associated with them.



[1] GALVALUME® is an internationally registered trademark of BIEC International, Inc. and some of its licensed producers.

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Types of Paint

The majority of the construction market for prepainted steel uses a cost-effective, two-coat paint system with primer and topcoat on the exterior side, and with primer and backer coat on the interior side. The coil coaters have the capacity to apply two coats on each side of the steel sheet in one pass through the paint line.

Paint companies discuss paints in terms of the polymer, or resin, used in the topcoat. The U. S. construction market uses five types of topcoats: fluorocarbon (PVDF or Kynar), polyester, silicone-modified polyester (SMP), polyvinylchloride (vinyl, PVC, or plastisol), and acrylic. Most paints use a blend of different types of resins, but the manufacturers generally describe them by their major resin constituent, for the sake of simplicity.

Most prepainted steel used for construction has a 1 mil exterior paint system (1 mil = one thousandth inch = 25 micrometers, μm). This includes a nominally 1 mil exterior coat and a thinner backer coat. The exterior finish should be 1.0±0.1 mil, which includes a 0.2-0.3 mil primer and 0.8±0.1 mil topcoat. Some fluorocarbon paints are sold as 2 mils systems. These could be a 1.1–1.3 mils primer with a 0.7–0.9 mil topcoat or may be applied in two passes through the coating line using two primer coats and one or two topcoats. Plastisols are sold as either 4 mils or 8 mils systems.

Types of Topcoat

Fluorocarbon paints use one of two fluorocarbon-based resins, Kynar 500®[1] or Hylar 5000®[1]. The large majority of fluorocarbon paints contain 70% of these resins. These paints are referred to as 70% Kynar, Kynar 500, 70% fluorocarbon, or 70% PVDF. Some fluorocarbon topcoats have only 50% PVDF resin and cannot use the trademarks. The formulation of the non-Kynar portion of the resin is proprietary.

Polyester, SMP and acrylic paints use proprietary resins and hence have more potential for performance variations than plastisols and fluorocarbon paint systems. Adding silicone-containing additives to polyesters improves resin stability. Silicone-modified polyesters have gained a reputation for decreasing the occurrence of chalking and fading performance. Waterborne acrylics have been developed that have greatly improved flexibility. However, the application costs of these paints are currently rather prohibitive. Plastisol paints use PVC resin, applied in 4 mil or sometimes 8 mil coatings. The coating line slows down for the application of plastisols, further increasing the cost.

Topcoats also have variations based on the type of color pigments used: ceramic, metal oxide or organic. Pigments lose color because of degradation by UV light. Ceramic pigments have outstanding resistance to UV degradation and are popular in the premium topcoats. Metal oxide and organic pigments are more common in the lower grade topcoats.

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Primer and Backer

Primers are also categorized by the main resin type and pigments present in the formulation. The main performance issues for primers are corrosion resistance and adhesion.

Four main types of primers are available based on different resin types: epoxy, polyester, polyurethane, and waterborne acrylic. Traditionally, most primers use epoxy resins. Paint companies are now offering more polyester, urethane and waterborne acrylic primers to improve the flexibility of the primer.

Virtually all construction market primers use chromate pigment. These chromate pigments are corrosion inhibitors, which provide excellent corrosion protection, particularly at cut edges. There is ongoing work within the paint industry to develop chromate-free primers. Chromate-free primers currently available have corrosion resistance trade-offs that limit their use.

Backers are usually neutral color polyesters and are not usually specified. The panel manufacturers can request the backside not be primed, but it is preferable to use the same primer as on the exterior side.

Paint Performance

Performance Overview

Color is paramount in selling paint but providing the desired color does little to differentiate paint systems. Paint can be provided with virtually any desired color. The primary selling point of paint performance is how well the color is retained, which is measured by fade and chalk. Other important factors in topcoat performance are gloss retention, flexibility, corrosion resistance and dirt retention. Table 1 defines various paint performance issues, while Table 2 shows typical performances of topcoats. Many of these criteria are measured quantitatively, which are discussed in the following sections.

[1] Kynar 500® is a registered trademark of Elf Atochem

[1] Hylar 5000® is a registered trademark of Ausimont USA, Inc.

Paint Systems Used in the Construction Market

Table 1. Paint Performance Issues	
Fade	Color loss from pigment degradation
Chalk	White residue from resin breakdown
Loss of Gloss	Lower reflectivity of the paint
Erosion	Loss of paint from weathering
Peeling	Loss of intact paint
Cracking	Cracks from forming operations
Checking	Paint cracks from shrinkage
Corrosion Resistance	Protection from corrosion where the paint barrier is not intact
Flexibility	The ability of the paint to stretch
Blistering	Bubbles formed in the paint film

Table 2. Paint Performance by Topcoat				
Issue	**Kynar**	**SMP**	**Polyester**	**Plastisol**
Fade	Excellent	Very Good	Good	N/A
Chalk	Excellent	Very Good	Good	Poor
Gloss Loss	Excellent	Very Good	Good	Poor
Checking	Excellent	Excellent	Excellent	Excellent
Edge Corrosion	Good	Excellent	Excellent	Excellent
Bend Corrosion	Very Good	Fair	Fair	Excellent
Flexibility	Very Good	Poor	Fair	Excellent

Fade

UV light decomposes paint pigments, making them permanently lighter. The degree of color loss depends on the amount of UV exposure, the type of pigment, the type of resin, and the color. In actual practice, paint companies generally mix the most colorfast pigments with the most UV-stable resins. Paint companies add ingredients to the paints called UV blockers to further lower the damage from UV light. Color should be measured only after removing the dirt and chalk. The exact procedures are given in ASTM D2244 and ASTM E308.

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The Measurement of Fade

Color can be described by three factors: the lightness, the hue and the chroma. The lightness value indicates the degree of the lightness or darkness of the color. The hue is what color it is. The chroma is how intense the color is. The color is commonly measured on a color meter with three values: L, a and b. The change in the overall color is ΔE:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

L – The lightness on a scale of 100=white, 0=black.

a – Negative values are green, positive values are red. Intensity increases as the value further from 0.

b – Negative values are blue, positive values are yellow. Intensity increases as the value further from 0.

ΔE values are the units described in paint warranties as color difference. For example, a color change of 2 in L, 4 in a, and 4 in b would have ΔE=6. This would not violate a paint warranty that sets a limit of 8 units of color change. Most people can see color differences of ΔE=1 to 2, if the colors are side by side. Color differences of ΔE=3 to 5 can be remembered.

Chalk

Chalk is the loose white material on the paint surface that remains after extensive exposure to sunlight. It is the remnants of resin and pigments, broken down by the weather, in particular UV light. The chalk makes the building appear to be a lighter color. Owners worried about fading may mistake the reversible color loss of chalking with the permanent color loss of fade. Washing off chalking can greatly restore the original color. Figure 2 shows the color changes that can occur from fade and chalk.

The chalk rating depends on the wiping method and uses standards of 2, 4, 6, 8, and 10. Ten is no chalk wiping off. The procedure is described in ASTM D4214.

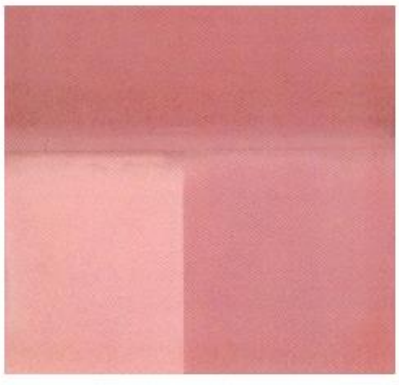

Figure 2: Red paint with no exposure (top) and full exposure (bottom), faded with chalk (bottom, left), faded with chalk washed off (bottom, right).

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Gloss Retention

A glossmeter measures gloss, typically at a 60° angle. Gloss is simply the percentage of light that reflects rather than diffuses from a surface, painted or not. The reported values are percent of gloss retained. Higher gloss makes a building look brighter, but higher gloss is more easily damaged and shows imperfections more clearly. ASTM D523 gives the procedures for measuring gloss.

There are two reasons for loss of gloss: (1) Natural weathering over time will roughen the paint surface. This type of gloss loss is permanent. (2) Buildup of chalk and dirt on the paint. Washing off chalk and dirt restores gloss lost for this reason.

Crazing, Checking, Cracking and Flexibility

When the paint cracks, it is due to stress that exceeds the flexibility tolerance of the paint. Cracking is dependent on the metallic coating, topcoat, primer and amount of stress. The paint system is stressed three times: in the curing process, in the forming process, and with natural exposure.

There is some non-uniformity to the shrinkage that occurs as the paint cures and hardens. The cracks created by this mechanism are rare in coil coated products. The paint systems for prepainted coil coated steels are designed to have the adhesion and flexibility to tolerate subsequent forming operations. When the strain induced in severe forming operations exceeds the flexibility of the coating system, fine cracks, or crazing, occurs in the paint film. To avoid this issue, the paint system chosen should be carefully matched to the forming operation. A U. S. Steel technical representative can assist in making this choice, which should preferably be made at the design stage. Typically, the most flexible paint systems are the plastisols and fluorocarbon systems, while the SMPs and polyester systems are less flexible. The paint flexibility can also be improved by using the process of warm roll forming which is especially useful in cold climates (see U. S. Steel Technical Bulletin on Warm Roll Forming of Prepainted Steel Sheet).

Outdoor exposure also introduces stresses to paint. As residual solvent leaves the coating and UV light degrades the resin, paints may lose their initial flexibility. They may then crack due to natural expansion and contraction of the coating from moisture and temperature variations. The resulting random pattern of fine cracks is known as checking.

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Corrosion Resistance

Paint provides additional barrier protection to the underlying metallic coated substrate, which can provide many years of useful service even in the bare condition. This is because the painted steels U. S. Steel provides for the construction market are either hot-dip galvanized or GALVALUME® Coated Steels. Each of these coatings provides galvanic protection to the steel substrate. If the coating becomes damaged and the steel substrate becomes exposed at cut edges, the zinc in the coated steels is sacrificed to protect the bare steel. Over time the zinc in the painted hot-dip galvanized steel will be consumed, undercutting the paint in these areas where steel is exposed, at which point the paint will flake off. The panel will then require repainting. However, GALVALUME® Coated Sheet Steel will provide galvanic protection to the steel due to the zinc component and barrier protection from the aluminum component since it has both zinc and aluminum in the coating. When the zinc is consumed in protecting damaged areas or cut edges, the aluminum in the coating remains such that the paint layer on painted GALVALUME® Sheet is not undercut.

The design of a paint system to protect the underlying coated steel substrate also involves the choice of pretreatment and primer system, each of which can provide considerable additional corrosion protection in damaged areas since they contain corrosion inhibitors.

The effectiveness of these components of the paint system in providing further resistance to corrosion is a major consideration in U. S. Steel's evaluation of paint systems to be qualified for use on its prepainted products for the construction market.

Paint Warranties & Choosing Paint

In addition to the performance criteria discussed above, there are other factors that should also be considered:

- The warranty offered
- The service provided with the paint
- The total applied paint cost

Most paints come with a warranty that guarantees certain aspects of the paint performance. A typical warranty might contain a 20-year guarantee against peeling, checking, blistering and limits on the fading and chalking. Typical limits might be a $\Delta E<5$ and a chalk rating of 6 or more.

U. S. Steel offers a 25-year perforation warranty on prepainted GALVALUME®. To obtain the warranty, a qualified paint system must be applied on one of the U. S. Steel qualified coil coating lines. The coil lines must use a qualified paint pretreatment.

Paint Systems Used in the Construction Market

Each of U. S. Steel's paint suppliers (AKZO Nobel, Sherwin Williams, and PPG Industries) can identify its qualified paints. With this system, U. S. Steel ensures the best quality of prepainted GALVALUME® Sheet.

Even with the best painted steel, situations occur that may require help from the material supplier. Having access to quick, reliable help may be the difference between a one-time sale and long-term customer.

U. S. Steel offers a single invoice option to simplify the supply of prepainted steel products. This option allows our customers to order exactly the paint quality required for a given application in the quantities needed. U. S. Steel is responsible in these cases for ensuring that the right product is delivered at the right location, at the right time. Any problems with the products are then dealt with quickly and efficiently by our customer service personnel.

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