Decorative coatings vs industrial coatings

In the second of his series of six articles on coatings, Prof. A S Khanna, Retd. IIT Bombay, Chairman SSPC India, turns his attention to decorative and industrial coatings. Amongst others, this article indicates market sizes, discusses selection criteria for industrial paints, looks at coating solutions for various types of environment and outlines what is meant by coating durability.

Figs. 1a and 1b: Examples of high performance coating (a) glass flake reinforced polyester coating to achieve1000µm in one coat (b) underwater coating on the tidal zone

Introduction

One of the easiest techniques of material protection is paint coating, which serves primarily two purposes: aesthetics and corrosion prevention. Based on this, paint coatings can be broadly categorised into two terminologies: decorative coatings and industrial coatings. The primary purpose of decorative coatings is to improve the aesthetics of a surface while also making it look attractive and colourful. In some instances, other advantages such as increased strength and durability may also be realised. A thorough approach to selection, preparation and application helps to ensure that decorative coatings provide long-term satisfaction. Just to give one example – the inside walls and external surfaces of buildings and structures have quite distinct requirements. Water proofing, a glossy finish, and anti-graffiti protection are some needs for indoor surfaces, whereas exterior walls and roofs need paint coatings that are long-lasting, anti-fungal, UV light-resistant, hydrophobic, anti-dust-pickup, and quickly changing colours.

Now let's examine several criteria needed to select a decorative finish. It is crucial to realise that selecting paint only based on colour is not the greatest option. Instead, decorative paint should be selected first based on the substrate, which can be either, concrete, steel, plastic, or wood. The second crucial decision is whether to choose an inside wall or an external wall, depending on where the object is located. Even inside walls, it makes a difference if they are the main drawing room, bedroom, kitchen, or bathrooms. In terms of colour, atmosphere, and durability, all may have a slightly different option. For example, bathrooms and kitchens may have more moist environments than other walls.

Market for decorative paint

It has been discovered that the decorative paint market is significantly bigger than the related industrial sector on a global scale. According to a 2018 industry analysis, the decorative paint market accounts for around 68% of the overall USD 158 billion paint market. This proportion is now estimated to be between 75 and 78 percent by various surveys [1, 2].

Industrial coatings split-up

According to the coatings market, there was a USD 158 billion paint market in 2018, with 68% of it being decorative and the remaining 32% being industrial. The break-up of Industrial coating was as follows: Transportation, which includes the automotive industry, accounts for 19% of the market. General industry, which essentially implies painting steel structure in any industry, accounts for 16% of the market. Maintenance coating (14%) includes the application of surface-tolerant coatings, coatings for moist and wet surfaces, etc. Powder coating and automobile refinishing are the next (both at 9%). Marine still accounts for 5% of the market and mostly consists of naval constructions, ships, jetties, and offshore structures. In a significant portion of the market (5%) for coil coating, steel is directly coated with various paints on thin foils. The packaging industry has a much smaller market share of approximately 3%. According to the current market research estimates, the global paint market has reached USD 184 billion with a CAGR of 4.6% in the present, and consequently, changes in the other industrial sector would be comparable [3].

Selection criteria

As was already said, the first criteria used to select industrial paints is the type of resin used as the binder, which is classified into alkyd, acrylic, polyester, epoxy, and polyurethane based resins. For each, there are hundreds of formulations available to satisfy the

For brevity, the section about decorative coatings has been shortened. Readers interested in more details can find the full article on the VWIME Featured Stories galley: xxxxxxxxxxxx

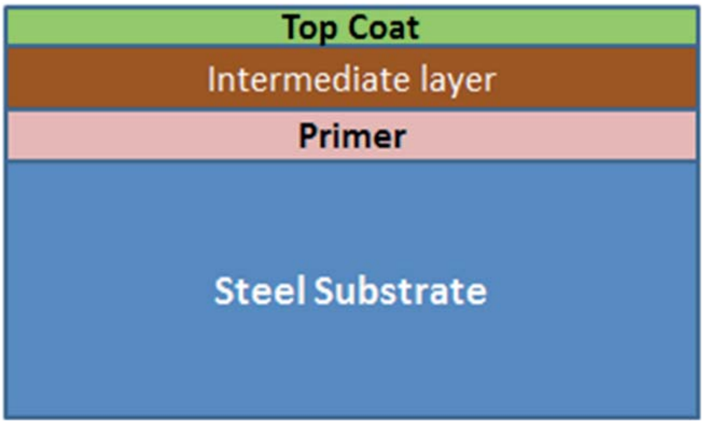

Fig. 2: Protection of steel structure using a three-coat composite coating system

functional requirements of the particular industrial challenge. The various paint coatings are separated into conventional and high performance coatings based on the modifications they have undergone. The latter category includes paint systems that may produce large coating thicknesses, such as several solvent-free paint systems that have been strengthened with unique pigments like MIO (mica iron oxide), glass flakes, and fibre, among many others. Such high performances coatings can be used in harsh conditions with high humidity levels and impart greater strength in addition to prolonged endurance.

Isophthalic ester-based polyester glass-flake coating is one such paint system that has gained a lot of popularity. It has the advantages of quick drying (due to radical-based mechanism), toughness (because to glass flakes), and increased thickness (due to lack of solvent). Such coatings are used on the splash zones of the piles of offshore constructions, which are the most corrosive locations in the C5M environment. (C1 to C5 are classifications of environments as defined by ISO 12944-2. For example, C3 means urban, C4 is coastal, C5 is offshore and C5M is offshore below the sea-level.)

The under-water coating, which employs the idea of water repellence during application, is another illustration of a high-performance coating. A basic epoxy and an amine hardener with several amine groups, such as cycloaliphatic amine, are used to create this coating [4].

The carbon to fluorine (C-F) bond provides the foundation for high performance coatings that can withstand environments that are strongly acidic, alkaline, or sewage-related. Resins with a fluoropolymer basis are necessary to create coatings that can withstand very acidic environments. The most corrosion-resistant coatings are those made of PVDF. Aluminium-Composite Panel (ACP) facades, which have a lifespan of 20 years or more, are used on the majority of multi-story structures have a thin 25 micron PVDF coating that protects the building from UV rays and acid rain.

With the proper selection and blending of epoxy resin and nanoparticles, a high performance coating that can withstand all acids and be applied on storage tanks for acids and alkalis is also possible. Very small nanoparticles distributed in a two pack epoxy system were used to provide a highly acid resistant covering for battery pit areas in ships and submarines. Such a covering can withstand temperatures of 250°C while also resisting all acids [5].

Using the silicon-oxygen (Si-O) bond is another way to provide a high performance coating, particularly for high temperature applications. From 300 °C and above, silicon base paint begins to resist temperature. Nevertheless, coatings made of poly-siloxane can withstand temperatures of up to 650 °C [6].

Durability

The endurance of the coating is one of the factors considered while choosing industrial coatings. Many industrial applications have requirements of corrosion protection in the range from a few years to 25 years or even longer. What contributes to the coating's increased durability? The coating system, which essentially consists of surface preparation, primer application, intermediate coat, and final top coat, must be examined in order to fully comprehend that. The longevity of paint is determined by a proper combination of four along with appropriate thicknesses.

Let's use the straightforward example of an external steel structure in a C3 environment that has a zinc base primer coat, epoxy as an intermediate coat, and aliphatic polyurethane as the top coat to demonstrate this. The choice of zinc primers can provide a life of between 1-2 years to 25 years for a set thickness of top aliphatic polyurethane (50 microns) and intermediate epoxy coating (100 microns).

A composite coating that comprises of a priming layer that is mostly a zinc-based coating and provides the coating with cathodic protection determines how long a painted structure will last. The next step is to apply an intermediate coat of epoxy coating, which serves primarily as a barrier against the elements, moisture, and

Table 1: Coating durability in terms of primer zinc content

Zn coating	% Zn on dry film	Corrosion effect	Durability (years)
Inhibited Zn coating	5-15	Very little (no cathodic protection)	2-3
Organic zinc rich coating	70-78	Reasonable cathodic protection	4-6
Inorganic zinc silicate	82-85	Good cathodic protection	6-8
Cold galvanized coatings ZRC/Zinga	95-96	Excellent durability	10-12
Metallized zinc coating	100% (3 times coating thickness)	Very very long life	25-50
Hot dip galvanization	100 (thickness 20-50 μm	Long life	35-60

contaminants such chlorides, carbon dioxide, and sulphur dioxide. The top polyurethane layer shields the intermediate epoxy coat from environmental elements like UV rays from the sun, rain, and snow. Figure 2 depicts this schematically.

Now let's change the primer layer by switching from one primer to another in a way that changes the amount of zinc in the coating, which essentially increases the coating's cathodic protection of steel and increases the coating's longevity. Table 1, column 2 lists the corresponding zinc levels for each zinc-based primer, and the last column lists the coating's durability. Thus, it is abundantly clear that a thermally sprayed zinc coating that provides 150 microns of 100% zinc or hot-dip galvanised steel, where a chemical layer of zinc is formed, can provide a life as high as 25 years or even longer than an inhibited epoxy coating with a zinc concentration of just less than 10-15%.

Now let's talk about a specific coating system, such as an epoxy intermediate coat of 100 microns and a top polyurethane coating (PU) of 50 microns that is appropriate for a C3 environment and has a life expectancy of 6–8 years. Now, if the environment changes from C3 to C4 or C5, all you need to do to get a life of 6–8 years is increase the coating thickness of the intermediate epoxy coat to 200 microns for C4 and 250–300 microns for C5. Table 2 provides an overview of the durability attained in different systems with coating thickness and type for C3-C5 settings for externally exposed utilities and internally exposed utilities [7]. The choice of coating for various internal and immersion systems as well as for underground pipelines is similarly shown in Table 3. If the fluid is more corrosive, like sewage water or glycol, a high-performance epoxy coating with glass flake is more durable. Nevertheless, for immersion service, such as the storage tank for oil, crude, and process water, a simple solvent-less epoxy coating of thickness 500 microns is sufficient. As was already said, a sturdy 3 LPE system is preferable for subterranean pipelines while a polyester glass flake is more reliable for splash zone applications. As a result, practically all industrial systems have solutions in Tables 2 and 3 [7].

Table 2: Description of the type of coating required and number of coats required for different corrosive environments [7].

Environment Category as per (ISO-12944-2)	Surface preparation required as per ISO 8501	Coating system	No. of coats	DFT (µm)
C 3 Non-immersion Medium corrosion (Temperature up to 120°C)	Sa 2.5	Medium durability 1 coats of alkyd 1 coat of alkyd modified with urethane Long durability Primer – zinc-rich epoxy Intermediate – 2 pack epoxy Top coat - 2 pack aliphatic PUR	 1 1 1 1 1	 50 50 50 100 50
C 4 Non-immersion (High corrosion)	Sa 2.5	Medium durability Primer: Zn-rich epoxy Intermediate: epoxy MIO Top coat: 2 pack aliphatic PUR Long durability Primer: inorganic Zn- Silicate Intermediate: epoxy MIO Top coat: 2 pack aliphatic PUR	 1 1 1 1 2 1	 50 50 50 75 150 50
C 5 Non-immersion Very high corrosion (Temperature up to 120°C	Sa2.5	Medium durability Primer: inorganic Zn- Silicate Intermediate: epoxy MIO Top coat: 2 pack aliphatic PUR Long durability Primer: inorganic Zn- Silicate Intermediate: high build epoxy MIO Top coat: 2 pack aliphatic PUR	 1 2 1 1 2 1	 50 150(2x75) 50 50 200 (2x100) 50
C 3 Non-immersion Medium corrosion (Temperature up to 400°C	Sa2.5	Medium durability Aluminum coating Long duration Primer: inorganic Zn- Silicate Top coat: silicon based coating	2 1 2	250 50 200
C 3 Non-immersion Medium corrosion (Temperature up to 600°C)	Sa 2.5	Medium durability Primer - silicon based Top coat: polysiloxane	 1 2	 50 250

Table 3: Different coating system under internal and immersion systems along with underground pipelines [7]

Environment Category as per (ISO-12944-2)	Surface preparation required as per ISO 8501	Coating system	No. of coats	DFT (μm)
Immersion service Tanks for fuel, oil, crude, chemicals and process water	Sa 2.5	Solventless spoxies	1	500
Immersion service Sewage lines, water treatment facilities	Sa 2.5	Glass-flake epoxies or Combination of glass- flake and reinforced epoxies	1 or 2	1000 or more
Immersion service Splash zone in sea water Underwater	Sa2.5 HA 2	Polyester glass-flake Water-repellent epoxies	1 2	1000 2x400
Immersion service Water jetties Sea water	Sa 2.5	Glass-flake epoxy or Novolac epoxy	1 or 2	1500-2000
Immersion service Freshwater treatment facilities, locks and gates	Sa 2.5	Solvent-less epoxies	1	1000
Underground structures Gas pipelines Water pipelines	Sa 2.5	External Oil & Gas 3 layer PE (FBE primer, adhesive and PE) Water pipelines Coal tar or tar epoxy, tar-urethane Liquid epoxy, elastomeric PU	3 1	2000 – 3000 3000-5000 700-1000

Conclusions

Paint coating is integrated into our daily lives. In addition to safeguarding our resources and industrial infrastructure, it also makes our homes, offices, and public buildings more attractive, shiny, and colourful. Since it covers our personal living spaces, work spaces, as well as a significant number of consumer durables, such as gazettes, we use in our daily lives, decorative paint dominates the coating market. The industrial market is separated into various segments, each with its own needs and requirements. The automotive industry is quite vast, and in addition to corrosion protection, some ornamental elements are also necessary. The main goal of new research and novel formulations is industrial application, which is extremely difficult. Because of this, a number of new terminologies are being used in industrial paints. The very basic recommendations in this article might help you visualise the wide range of paint finishes.

About the Author

Dr. A S Khanna, a retired Professor from Indian Institute of Technology, Bombay, after 27 years of teaching and research, guiding 27 Ph.D's, 125 Masters and creating research expertise in High Temperature Corrosion, Coatings, Surface Engineering, Corrosion of concrete structures and nano-coatings. He has won several International Awards such as Humboldt Fellowship from Germany, Royal Norwegian Fellowship from Norway, Fellow of Japan Key Centre and worked as visiting Professor in Germany and France. He has written three books and edited four books. He has published more than 300 papers in several International and National Journals with more than 4500 citations. He is a coating expert and is associated with Hindustan Zinc for several assignments related to galvanization and its applications, Sterling & Wilson for selection of sites for solar power plants, oil & gas industry for consolation on coatings for underground pipelines and offshore structures.

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