ZINC MATTERS

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ZINC PRIMERS: AN OVERVIEW

Metallic zinc as a protective primer

It is generally accepted that particles of metallic zinc applied to a steel surface in a paint matrix, in the form of a zinc primer, provide protection to the steel by a process of cathodic protection. In the presence of moisture as the electrolyte, the steel forms the cathode and the zinc the anode in the resultant corrosion cell. The steel, being the cathode, does not corrode whilst the zinc, being the anode, corrodes preferentially and protects the steel. This protection continues until the zinc in the paint matrix is consumed or depleted.[#1]

Hot dip galvanizing vs zinc rich paint

It must be remembered that it is metallic zinc that affords cathodic protection to steel and the extent of protection offered is directly proportional to the coating thickness with respect to hot dip galvanizing. A further factor to be considered is the environment to which these coatings would be exposed.

Care should therefore be taken when selecting zinc based coating systems for chemical environments. Zinc, being an amphoteric metal, is attacked by both acids and alkalis. Zinc should only be used in the pH range 6 to 12.5.[#2]

When considering zinc rich paints, only those that contain sufficient quantities of metallic zinc dust will provide cathodic protection. There must obviously be sufficient zinc particles present to ensure that they are in electrical contact with each other in order to provide a common anode. Individual isolated zinc particles dispersed in the paint binder will not provide protection as they would essentially be insulated from the substrate and each other. In accordance with ISO 12944, all zinc rich paints should contain a minimum of 80% zinc in the dry film in order to function as sacrificial primers.

A "Duplex Coating" is a term first introduced by Jan van Eijnsbergen of the Dutch Hot Dip Galvanizing Institute in the early 1950's. It describes the protection of steel by over coating hot dip galvanizing with an organic coating system. The purpose is to provide additional corrosion resistance, easy visibility, camouflage, or when a pleasing aesthetic appearance is necessary.

Duplex coating systems provide synergy by virtue of the fact that the durability of the combined hot dip galvanized / organic coating system is greater than the sum of the separate durabilities of the hot dip galvanizing and an organic coating layer applied directly to the steel substrate.

The reasons for this synergistic effect are as follows.

When moisture, oxygen and pollutants diffuse through a paint coating onto steel, rust soon forms at the interface. Since rust (a mixture of various hydrated iron oxides with varying compositions) has a volume which is approximately twice to three times the volume of the steel from which it has been formed, the paint coating will lose contact with the substrate and, depending upon its adhesion and cohesion, will start to crack and/or flake off.

When hot dip galvanized steel is the base of a paint system, the occurrence of moisture, oxygen and pollutants at the zinc / paint interface causes the pure zinc (or eta layer) to corrode slowly. However, these zinc corrosion products (mainly zinc oxide and zinc hydroxide) have a volume which is only 15 - 20% more than the volume of zinc from which they have been formed. These zinc corrosion products will block off small pores, craters or cracks in the paint coating[#3], thus conserving its protective properties over an extended period, provided that adequate adhesion of the paint coating was initially achieved.

The benefit of a metallic zinc primer such as hot dip galvanizing under an organic coating system is illustrated by the comparative photographs seen in *Figure 1*. The photograph on the left in *Figure 1*, shows a powder coated mild steel panel that has been exposed in a salt spray cabinet for 2 000 hours. The rust staining weeping from the scribe cuts shows that the underlying steel is corroding where the salt spray has gained access to the substrate. The coating adjacent to the scribes is being lifted by the voluminous iron corrosion products. The photograph on the right in *Figure 1*, shows a powder coated panel made from continuous hot dip galvanized sheeting – coating class Z275 (equates to about a 20µm coating thickness). In this instance the metallic zinc primer has provided cathodic protection to the underlying steel at the scribe cuts. The surrounding zinc is sacrificing itself to protect the steel, forming white zinc corrosion products. The solid volume of the zinc corrosion products is small and therefore the coating adjacent to the scribes has suffered little damage. After the same 2 000 hours period there is still sufficient zinc to prevent corrosion of the underlying steel. The sacrificial nature of zinc at the scribe points will in time deplete the surrounding zinc coating and as it recedes, leaving uncoated steel at the scribe point[#4], localised corrosion will commence. Maintenance painting repairs would then be required before the steel substrate becomes damaged.

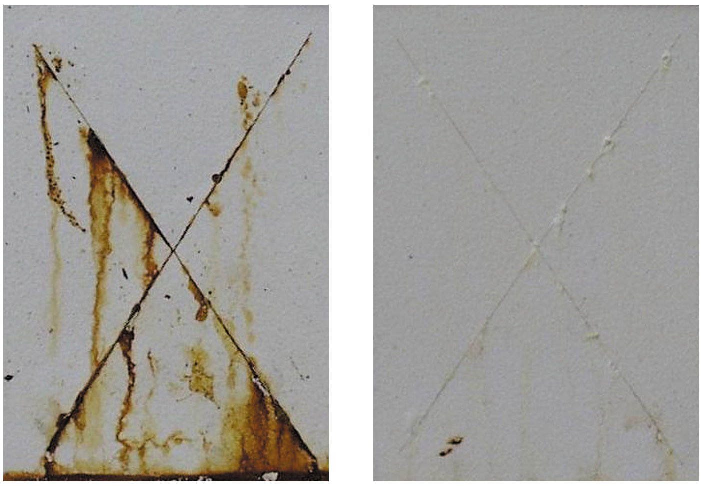

Figure 1: (Left) Powder coated mild steel – 2 000 hours salt spray.[#1]

(Right) Powder coated continuous hot dip galvanized sheeting – Z275 – 2 000 hours salt spray.[#1] (right).

[#1] Both coatings in photos 1 & 2 were scribed down to the steel substrate prior to exposure to the salt spray test.

In extenuating circumstances such as possible design restrictions, size of component, geographical location of the fabricator in relation to the galvanizer, or where hot dip galvanizing is impractical or impossible, it may have to be substituted by either inorganic or organic (epoxy) zinc.

It is beyond the scope of this article to cover the detailed pros and cons of hot dip galvanizing versus zinc rich paints but one of the main factors for consideration remains costs. A number of articles comparing the relative costs of hot dip galvanizing versus painting have been published.[#5]

The essential difference that must be appreciated is that hot dip galvanizing costs are calculated by mass of steel hot dip galvanized, whilst painting costs are based on area painted. Tables are available for most steel sections giving surface area by mass.

As a rule of thumb the following can be used:

Extra light steel	more than 40m^2/ton
Light steel	30 to 40 m^2/ton
Medium steel	20 to 30 m^2/ton
Heavy steel	less than 20 m^2/ton

In hot dip galvanizing, steel is subjected to a routine cleaning process, including degreasing, acid pickling and fluxing, with intermediate water rinsing, thereby creating a thoroughly clean surface, essential for hot dip galvanizing to take place. The resultant coating thickness is dependent on several factors including, chemical composition of the steel, steel thickness and surface roughness, as well as a number of other less important factors. In steel of thickness equal to or greater than 3mm but less than 6mm, the mean coating thickness is required to be at least 70µm but on steel thickness greater than 6mm the coating must be 85µm.

The photos show hot dip galvanized steel in an architectural application at the National Library, Pretoria, South Africa.

The painter will abrasive blast clean the steel and then spray apply a suitable 75 micron thick (inorganic or organic) zinc rich primer coat for a protective coating system at a cost based on the total area of steel he has painted.

Case histories have shown that for steel sections up to some $35m^2$/ton it is more cost effective to blast clean and paint whereas for steel sections with greater than $35m^2$/ton, it is more cost effective to hot dip galvanize. Obviously this cut off point varies with raw material and labour costs at any point in time. On the other hand the hot dip galvanizing will require thorough cleaning before the primer or intermediate coat can be applied. [#6]

The point is, however, that both methods of providing the required metallic zinc primer can be cost effective, depending upon circumstances. It is for this reason that in recent years both options have been given in protective coating specifications, leaving the final decision whether to hot dip galvanize or paint, up to market forces.

Many fabricators have a painting facility in their shops such that the fabricated steel moves through the wheelabrator and into the paint shop where it receives the primer, intermediate and sometimes the finishing coat before it is transported to site. If the steel is to be hot dip galvanized the fabricator has to transport the steel to the galvanizer and return it before applying the subsequent paint coatings. In order to make hot dip galvanizing cost effective in this instance the galvanizer needs a painting facility in order to apply the top coats without incurring further transport costs. The concept of applying paint at the galvanizers premises is available at a number of galvanizers throughout South Africa.[#7]

Clearly hot dip galvanized coatings and paint coatings complement each other in the protective coatings industry. However, there is still a perception in the market place that the galvanizers and paint manufacturers are in competition with each other.[#8]

Expert footnotes

#1 Zinc rich coatings can come as organic zinc rich paints or inorganic zinc rich paints and each has its own specific properties and role in the coating world. While inorganic zinc rich primers are tricky to apply they provide very good corrosion protection. Organic zinc rich coatings are formulated with a variety of binders e.g. epoxy or polyurethane and are relatively easy to apply.

#2 Although zinc is amphoteric, i.e. will corrode at pH less than 6 and above 12.5, if sufficiently over coated with a comprehensive organic coating system, it will provide better protection than the same paint coating system applied over plain carbon steel.

#3 All paint coatings in time become porous and this allows moisture to penetrate the coating.

#4 In comparison to a coating thickness of about 20µm, produced on class Z275 continuously galvanized sheet (ISO 3575), general hot dip galvanizing (ISO 1461) produces a thicker coating:, 45µm for steel less than 1.5mm thick to 85µm for steel greater than 6mm. The thicker the available coating, the longer the period of sacrificial protection at damaged areas such as the scribe points detailed in the article, before the onset of localised corrosion.

#5 Recent price comparisons indicate that hot dip galvanizing on its own is competitive when compared to an abrasive blast and a paint coating of about 75µm DFT of inorganic zinc rich paint, in steels from ultra light (70 to $120m^2$/ton) to heavy steel ($25m^2$/ton). This comparison excludes the cost of independent substrate and coating inspection for the painted steelwork and additional transportation of the hot dip galvanized steel.

#6 A hot dip galvanized coating comprises a series of Fe/Zn alloy layers making up between 50 and 85% of the coating.

#7 In our opinion, the logistics of additional transport, concerns not only the galvanizers but many steel fabricators. Faced with stringent environmental regulations for applying paint, lack of skilled painting staff and general downsizing of expertise, this then forces many fabricators to outsource the painting stage. Furthermore, there are many hot dip galvanizers who have gained the necessary expertise to prepare and apply at least the primer coat, if not the entire coating system. Additionally, where this expertise is not available, some galvanizers can provide industrial painters with floor space, in which preparation and subsequent painting may take place.

#8 While there is merit in using a duplex coating where it is required, such as in the instances referred to in the article, there will in most instances be co-operation between the paint and hot dip galvanizing industries. However, when a single coating is specified that must be appropriate and cost effective, there will always be competition between the players of both industries.

International Zinc Association
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