

INORGANIC ZINC SILICATE COATINGS: FALLACIES AND FACTS

R. Francis¹

¹R A Francis Consulting Services, Ashburton, Vic, Australia

SUMMARY: A single coat inorganic zinc silicate can provide long-term protection to steelwork in many atmospheric environments. As a single coat system applied relatively thinly, it is also very economical and can allow rapid throughput of coating work. However there are some disadvantages and costs to be incurred when using this material. These have led to a number of myths and misunderstanding regarding inorganic zinc silicate coatings which have led to its misuse, failures or neglect. This paper discusses some of these fallacies and points out some of the issues involved in selection, application and maintenance of these coatings.

Keywords: Inorganic zinc silicate, application, environmental conditions, thickness, failures, overcoating

INTRODUCTION

A single coat inorganic zinc silicate (IZS), whether solvent borne (SB) or water-borne (WB), can provide long-term protection to steelwork in many atmospheric environments. As a single coat applied relatively thinly, it is also very economical and can allow rapid throughput of coating work. However, as with many attractive propositions in all aspects of life, there are some disadvantages and costs to be incurred when using this material. These have led to a number of myths and misunderstanding regarding inorganic zinc silicate coatings which have led to coating failures as well as its misuse or neglect. This paper discusses some of these fallacies and points some of the issues involved in selection, application and maintenance of these coatings.

Fallacy: Inorganic zinc coatings protect steel by cathodic protection.

The difference in electrochemical potential between zinc and steel, and its utilisation to protect steel, is well-known even outside the corrosion protection industry. Zinc metal electrically connected to steel in a conductive electrolyte is anodic and will preferentially corrode, making the steel cathodic and so it is protected. The widespread use of zinc anodes to protect submerged and underground structures is the obvious manifestation of this property.

However, when zinc is used as a coating, especially the use of zinc dust suspended in a binder, other protective processes come into play. At a scratch or gap in a zinc-rich coating applied to steel, there is no doubt that the zinc particles corrode preferentially protecting the steel adjacent to the bare area. The zinc particles will continue to corrode protecting the bare steel area until the region becomes too large and there is insufficient throwing power to continue providing cathodic protection. However at the edge of the bare area, zinc will continue to corrode in preference to the steel spreading laterally, preventing the undercutting of the coatings which is observed in break down of zinc-free coatings.

But in the regions where steel is not exposed, which will normally be the bulk of the coating if not the entire coating especially when new, the steel substrate does not corrode. This is not because of cathodic protection but rather the zinc coating is simply providing barrier protection. Oxygen, moisture and other corrosives react with the zinc particles at the outer surface of the coating, and do not permeate to the substrate. The corrosion products tend to fill the voids in the coating so the barrier effect can in fact improve with time. The corrosion products from zinc metal coatings do not have this feature as they remain on the surface and are more likely to be removed with continued exposure. It should also be noted that the silicate polymer network in an inorganic zinc silicate coating also provides a very effective barrier and silicate coatings without zinc can provide considerable durability even in quite corrosive environments (1).

So there are two mechanisms by which IZS coatings provide protection to steel. Most importantly, the zinc particles and silicate binder provide a barrier preventing the corrosives reaching the steel. Over time, this barrier becomes more effective

as zinc corrosion products fill the porosity. Only at scratches and other bare areas is there cathodic protection provided by zinc. These effects which provide protection in zinc powder coatings are shown diagrammatically in Figure 1(a).

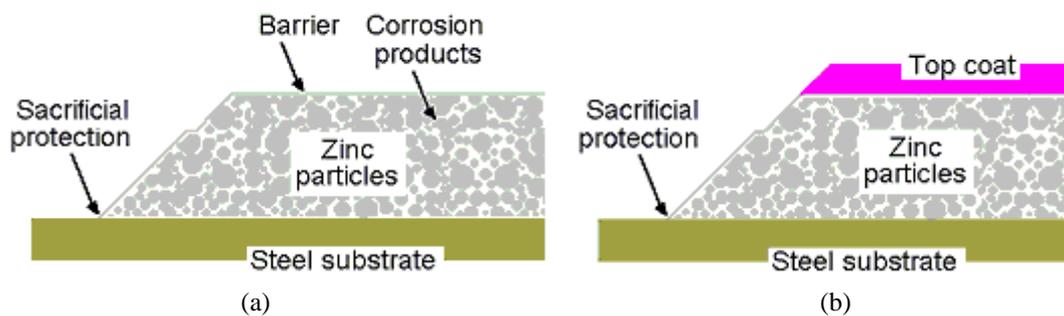


Figure 1: Protection mechanisms in a zinc-rich coating (a) without topcoat, (b) with topcoat.

Fact: Intact inorganic zinc silicate coatings provide protection to the steel substrate by the barrier effect of the zinc silicate. Over time, the porosity is filled with corrosion products and barrier effect increases. The zinc metal particles provide cathodic protection only where the steel is exposed, such as at scratches and gaps in the coating.

Fallacy: Inorganic zinc silicate is simply another paint and any painter can apply it.

This myth is perhaps the main reason for most failures of IZS coatings. Although the skills required to mix and apply it successfully can be easily learnt, treating IZS in the same way as other single or two pack paints can result in faulty application. Some of the special factors that must be taken into account when mixing and applying IZS coatings include:

- The mixed liquid must be filtered to minimise risk of clogging, but the painter must be careful not to throw away too much pigment. Maintenance of the proper zinc content is crucial for coating performance.
- Zinc pigment is heavy and will rapidly settle out. It must be continuously agitated. The mixed material should be kept moving and interruptions minimised. Lines must be cleared and the liquid agitated after any interruptions.
- The applicator must apply the coating as a wet coat in even, parallel passes. This is especially true for the WB products which dry within a matter of seconds. Ideally, this should be as a single pass with 50 per cent overlap. This means the gun should be adjusted to apply half the required dry film thickness per pass.
- Temperature and humidity conditions are critical for proper curing (see later section).

In some ways, it is better to think of inorganic zinc as a layer of concrete rather than a layer of paint. Table 1 compares some properties of IZS to concrete as well as to epoxy zinc, a more typical paint coating. While there are important differences, IZS is closer to concrete in many ways than it is to an organic zinc coating.

Table 1: Comparison of properties of inorganic and organic zinc coatings to concrete.

Property	Concrete	IZS-SB	IZS-WB	Epoxy Zinc
Structure	Porous	Porous	Porous	Impervious
Effect of UV	None	None	None	Chalks and degrades
Initial drying	Loss of water	Loss of solvent	Loss of water	Loss of solvent
Cure	Hydration (reaction with moisture)	Hydration (reaction with water)	Reaction with water and CO2	Cross linking of resin and hardener
Long term cure	Reaction with moisture	Cross linking	Cross-linking	No change
Change on weathering	Pores fill with reaction products	Pores fill with reaction products	Pores fill with reaction products	Chalking and chemical breakdown
Eventual Breakdown in neutral environment	Carbonation	Corrosion of zinc pigment	Corrosion of zinc pigment	Break down of epoxy binder, corrosion of zinc pigment

Like concrete, the heavy constituent can settle out from the liquid material during application. Baxter (2) considers a can of IZS to be like a bucket of sand in water, so needs to be continuously agitated to keep the heavy zinc pigment in suspension (Figure 2).

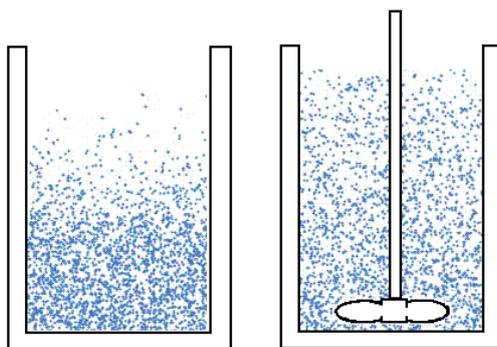


Figure 2: Pot agitation is necessary to keep the zinc in suspension.

Fact: IZS coatings have many idiosyncrasies during mixing, application and curing, and applicators must be experienced in their use if optimum performance is to be achieved.

Fallacy: The water-borne product provides greatly superior protection to the solvent-borne product in a single-coat system.

There are many reasons for belief in this fallacy. WB-IZS has been around for longer, and there are far more examples of its use. It usually has a slightly higher zinc content, and is often specified to a higher dry film thickness. In our part of the world, the 1994 version of AS/NZS 2312 gave, for example, a durability of 10 to 20 years in a marine atmospheric environment for WB-IZS but did not recommend SB-IZS at all for this environment. There were similar reductions in performance for the SB in other environments. As a result, the solvent-borne product has been less commonly specified as a single coat application. The 2002 update of AS/NZS 2312 reduced the difference in durability between the two types considerably, but the belief that only the water-borne product should be specified in severe environments has persisted.

However, close examination has shown the difference in performance between the two types to be minor. The WB-IZS is certainly harder with better abrasion resistance, but this is not relevant for most atmospheric applications. In accelerated Prohesion testing, Lofhelm et al (3) found the SB-IZS outperformed WB-IZS. However, relating accelerated to field performance is not always advised.

Single coat solvent borne IZS has in fact been used in many applications. Table 2 is a list of examples in Australia and New Zealand showing the durability of a specified 75 microns of ethyl silicate IZS from a survey taken in 2001 (4). This limited survey, while not confirming equality with the water-borne product certainly dispels the myth that the solvent-borne product provides inferior durability.

Table 2: Examples of the durability of single coat ethyl silicate inorganic zinc coatings applied in Australia and New Zealand

ISO category - Corrosivity	Structure	Location	Years life in 2001
C2 Low	Meat works	Hamilton NZ	19+
	Pipeline	Dungog NSW	25+
	Drayton colliery	Doito NSW	16+
	Springvale colliery	Lithgow NSW	13+
	Power station	Mt. Piper NSW	11+
	Power station	Loy Yang Vic	20+
	Power station	Wallerawang NSW	23+
C3 Medium	Sign gantries, Western Link bypass	Melbourne Vic	5+
	Power station	Vales Point NSW	25+
	Power station	Eraring NSW	23+
	Mini steel mill	Rooty Hill NSW	8+
C4 High	Gas plant	Longford Vic	23+
	Tank roof	Hastings Vic	21+
C5I Very high – Industrial	Century zinc mine process area	North Qld	4+
	Cadia gold mine process area	Orange NSW	4+

In a survey of 17 single-coat inorganic zinc coated bridges in Victoria (5), only one structure was protected with solvent-borne inorganic zinc, a bridge 22 years old. While a single structure does not allow definite conclusions to be drawn, it is interesting to compare its performance with those coated with the water-borne product. It did perform significantly poorer for its age than the water-borne counterparts, but, as shown by Figure 3, its poorer performance is most likely due to the rather low film thickness that was applied over parts of the structure. The regions of rust breakthrough were associated with these areas of low film thickness. The coating performed well where the coating was thicker. Interestingly, the maximum thickness on this structure measured was 336 microns, with a number of readings above 150 microns but, as with the water-borne product, no mud cracking was observed.

SB IZS has fewer curing limitations than the WB product, and there are other advantages associated with specification and use of solvent-borne product over the water borne zincs (6). However, properly applied, both types can provide excellent protection in severe environments. Specifiers need to be aware that both products will provide good protection and can be used interchangeably in many situations.

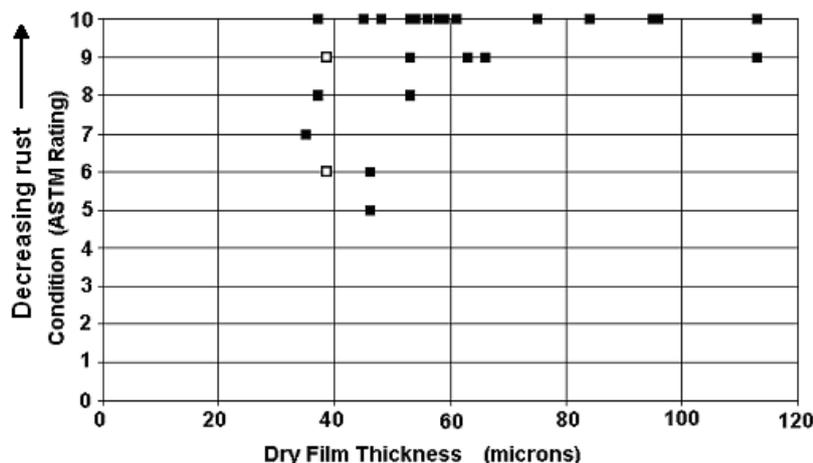


Figure 3: Condition of inorganic zinc coated bridges as a function of minimum measured DFT (■: water-borne, □: solvent-borne). (5)

Fact: Both single coat WB and SB IZS coating systems can provide excellent protection in many environments. Selection of the type should normally be based on likely application and curing conditions (see following section). Note that the application of a single 100 micron coat of SB IZS can be specified by reference to AS 4841-2006.

Fallacy: The same drying and curing considerations relate to application for both the WB and SB products.

The processes of both “drying” (loss of solvent) and “cure” (chemical reactions) are completely different for the two products so entirely different environmental considerations are appropriate during application. It needs to be recognised that just because the water or solvent has evaporated from the coating and the coating appears dry, this does not mean that the coating is cured. There will be considerable cross-linking occurring and this reaction continues for many weeks and even years. Salome (7) described in detail the acceptable conditions for application of the two products, and epoxy zinc for comparison.

For the water-borne product, the first stage is evaporation of the water, so warm, dry conditions are required. After evaporation of the water, one of the first reaction products during the cure is production of alkaline potassium hydroxide. Under normal conditions, this will neutralise through reaction with atmospheric carbon dioxide and moisture and allow the zinc silicate polymer to form, which becomes more insoluble and water resistant with time. However, heavy dew or water ponding will cause this hydroxide to attack the zinc or the unreacted silicate, causing spot rusting, blistering or a soft, uncured film (Figure 4). Heavy rain may wash the hydroxide out of the film, and this damage may not arise. Depending on the weather conditions, it may be weeks or months before the hydroxide is reacted or removed from the coating and a neutral surface is achieved.

Ideal conditions for the application of WB-IZS coatings are a surface temperature of 20 to 25°C, and an RH of between 40% and 50%. Under these conditions, curing to water resistance can be achieved in about 2 hours. The further away from the ideal conditions, the longer will be the curing time. The coating must be protected from rain or heavy dew during this period. Although not often stated, moving air is also important for drying any water-borne coating, and stagnant air conditions must be avoided.



Figure 4: Spot rusting and blistering on WB-IZS coating from alkali production as a result of condensation during curing (8)

For the solvent-borne product, the first stage is evaporation of the solvent which readily occurs even under cold conditions. After evaporation of the solvent, ethyl silicate reacts with water from atmospheric humidity (a hydrolysis reaction) to form a silanol and ethanol. The silanol molecules cross-link in a condensation reaction, reacting with zinc and moisture to form a zinc silicate polymer. No hydroxide forms and the coating becomes water insoluble within a matter of minutes. With alcohol as its solvent, it can be applied under cooler conditions than the water-borne, but SB-IZS does require high humidity to cure. Under conditions of low humidity, the coating “dries” but a soft, friable un-cured coating results.

Ideal conditions for application of solvent-borne IZS are a surface temperature of 20 to 25°C, and an RH of between 70% and 90%. However, they can be applied at a temperature down to 5°C and a relative humidity of at least 50%, although this should be at least 60% if the IZS is to be overcoated. The coating will cure under conditions of very high relative humidity, but evaporation of the solvent will be retarded and there is greater risk of damage from rain or condensation. Curing times will increase with cooler temperatures and lower humidity. Figure B1 in AS/NZS 3750.15-1998 gives typical curing profiles for a solvent borne inorganic zinc.

Figure 5 summarises drying and curing conditions for the two types of IZS coatings.

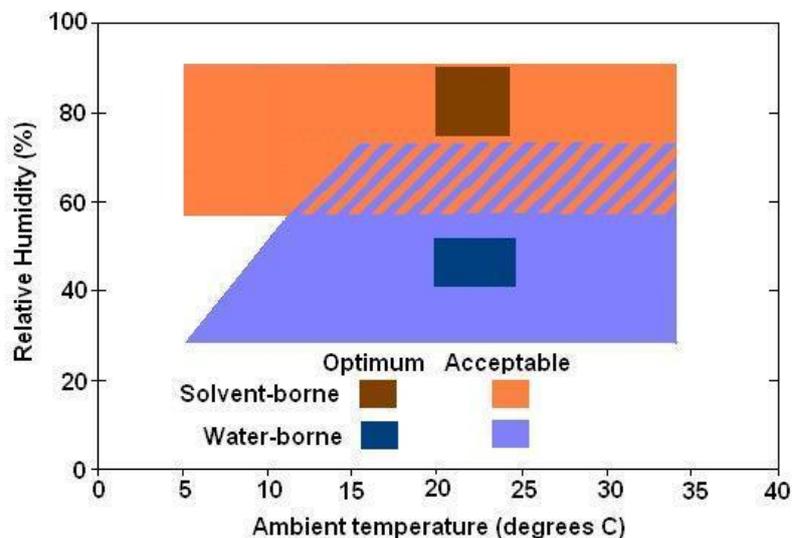


Figure 5: Temperature and Relative Humidity conditions for curing inorganic zinc coatings.

Fact: Application of WB-IZS requires warm, dry conditions, while the SB-IZS requires relatively humid conditions. In order to prevent an applicator being forced to apply an IZS coating under climatic conditions where it is not likely to achieve satisfactory cure, provision should be made by specifiers to allow either solvent or water borne zinc silicate coating to be used depending on prevailing conditions.

Fallacy: Minimising the film thickness to reduce the risk of mudcracking is critical when applying inorganic zincs.

One of the problems with IZS coatings, especially solvent-borne, is their tendency to mud crack when applied too thickly. This is a very real problem, and many applications on complex surfaces will result in cracking in corners and other difficult areas when the coating is applied too heavily. But mudcracking is not as serious as it may appear. Firstly, with many

formulations, it does not become visible unless the coating is some hundreds of microns thick (9). With the trained and experienced applicators as discussed above, keeping the thickness below such levels should not be a problem. Secondly, as discussed above, IZS is more like concrete than paint, and as with concrete, fine cracking should not be an issue. The corrosion products should fill in the cracks in the same way that fine cracks in concrete will often self heal. Finally, even if the steel was exposed, the zinc would provide cathodic protection preventing corrosion of the substrate.

As shown in Figure 3, it is critical that there is sufficient coating covering every part of the structure. In order to achieve this, the target film thickness should be such that there is little chance that there will be regions with less than about 75 microns of coating. To achieve this, skilled applicators should aim for around 100 microns. Dry film thickness Standards such as AS 3894.3 and SSPC PA-2 allow readings down to 80% of the specified minimum film thickness if the average is acceptable. Therefore, a specified minimum DFT of 100 microns means that the applicator is allowed to apply the coating in places down to 80 microns, but no lower. This should ensure that there is sufficient coating over the entire surface to minimise the risk of premature breakdown in low DFT regions. A thorough visual inspection should be carried out to ensure there is no severe mudcracking and loss of adhesion, but minor cracking can be left. There is certainly no requirement to check for its presence with a hand lens.

Fact: Regions of low DFT are far more likely to allow premature coating breakdown than regions showing minor mud cracking. Severe mudcracking should be repaired, but it is better to concentrate on achieving sufficient coating thickness. It is recommended that IZS be applied to a minimum specified thickness of approximately 100 microns.

Fallacy: An inorganic zinc coating cannot be repaired with itself.

This is a popular fallacy with repair recommendations ranging from complete removal to overcoating with epoxy zinc. In fact, IZS can be recoated with itself with few extra considerations that differ from repair of other coating types, although as with original application this does require care and skill.

Once again it is the porosity of the coating that must be taken into account. If the coating is found to be too thin after application and an extra coat is required, the porosity has not had a chance to fill with corrosion products and the silicate solution from the repair coat will migrate into the voids leaving a friable and powdery surface. According to Baxter (2) the liquid content of the repair coat should be increased by 10 to 15% so that there is sufficient liquid to prevent the surface layer becoming underbound and lack in adhesion. Spraying the zinc with water before applying a repair coat to create corrosion products that fill the porosity has also been suggested.

Once the coating has aged, porosity is no longer an issue. As with any other repair coating, the surface must be properly cleaned before applying a topcoat of IZS. Zhang and Walker (10) investigated a number of surface preparation techniques and a number of different repair coatings over aged inorganic zinc (Figure 6). They found that, after eight years of exposure, repair with SB and WB IZS both performed very well and were recommended. Zinc-rich moisture cured urethane and epoxy zinc repair coatings did not perform as well with white rust, coating deterioration and, in the case of the epoxy zinc, red rust. For surface preparation, sweep abrasive blasting was most effective, followed in order by power tool cleaning, low pressure water cleaning with abrasive injection, and low pressure water cleaning. However, the effect of surface preparation was more significant for the poorly performing repair coats, and made little difference to the IZS repair coating. Riding (11) also carried out repair tests on panels and found the method of surface preparation, whether scrub with a brush, low pressure wash, scrub and wash or wash and sweep blast made little difference to adhesion. It appears as long as the surface is thoroughly clean and free from loose contamination, then it will be suitable for overcoating.



Figure 6: Overcoating trial at Graham Street overpass.

Zhang and Walker found that the adhesion after eight years of all four repair coatings was very good to excellent in all cases. However, the initial adhesion of a maintenance IZS coating is poor (9, 11). This is because full cure of these coatings

takes a long time and it is only when the coating is almost completely cured (which may be some months) that the bond between the old and new coating has fully developed. It is actually cohesion within the repair coat rather than adhesion of the new coat to the old coat that needs to develop. Repair with IZS should not be carried out where initial adhesion is critical, but such situations should not be common for structural steel in most atmospheric applications.

Fact: Low build areas after application can be built up with the same coating if porosity of the film is taken into account. When a single-coat ISZ coating system needs maintenance, it can be repaired with another coat of IZS, water or solvent borne depending on prevailing conditions. Sweep blasting is ideal preparation, but any normal surface preparation method can be used. Initial adhesion of the repair coat may be minimal, but this will improve with time and the repair coat will merge gradually with the existing coat.

Fallacy: A top coat will provide additional protection to a single-coat IZS coating.

For conventional coatings, more coats are usually better, as these will provide better protection against UV damage and permeation by oxygen, water and other corrosives as well as minimising the risk of areas with low build. However for IZS coatings, most of these considerations do not apply. They are not affected by UV and, as explained above, they are permeable coatings and the formation of zinc corrosion products actually contribute to improved protection with time. Applying a top coat prevents continued curing and the formation of the protective corrosion products. Furthermore, the cathodic protection that protects bare areas of steel is also reduced by a top coat as shown in Figure 1(b). Many tests have shown that topcoating is not necessary and in some cases can actually be detrimental to coating system durability (12).

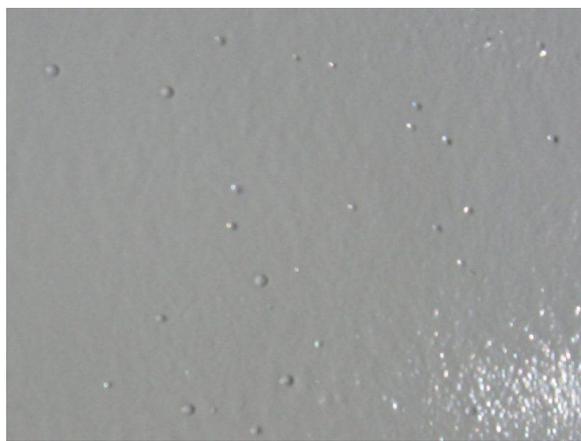
Fact: IZS, whether WB or SB, performs best when uncoated. Top coats should only be applied if colour is required, and then an epoxy zinc primer system that is easier to apply and has fewer drying and curing restrictions provides similar performance in a multi-coat system.

Fallacy: If topcoating IZS is necessary, it is a relatively straightforward activity.

As mentioned above, topcoating should only be carried out when colour is required or there is some other specific requirement that cannot be met by an un-topcoated IZS system. Topcoating adds to the observations and activities required by the applicator of the un-topcoated systems described above. The IZS must be thoroughly cured and any contamination and dry spray must be removed. Curing requirements are even more important and critical than for the un-topcoated systems as, once the topcoat is applied, no further curing can take place. Topcoats can fail by peeling of the topcoated and part of the zinc primer from the surface, a failure known as zinc splitting, as shown in Figure 7(a) (13). This arises because of the lack of cohesion within an uncured IZS coating.



(a)



(b)

Figure 7: Zinc splitting (a) or bubbling (b) can result from overcoating inorganic zinc if proper procedures are not carried out.

There are other considerations when applying topcoats. Most importantly, the porous nature of the zinc can cause bubbling (gassing) or pinholing of the topcoat, usually resulting in a cratered appearance once dried as shown in Figure 7(b). This arises as air within the porous IZS escapes. There are a number of techniques used to minimise the risk of this, including use of a low DFT mist coat, application of a layer of the topcoat thinned down considerably or use of a compatible tie coat (14, 15). These will penetrate into the porosity of the zinc coating and drive out the air. The subsequent coating should not then be affected by bubbling and pinholing. Ideally the topcoat should be applied after the ISZ has been exposed to the weather for several weeks, and these problems are rare when topcoating shop primed steel on site after erection.

Water borne inorganic zincs should not normally be topcoated because of the additional problem of possible residual alkalinity which may destroy any applied coating. However, WB-IZS topcoated with an acrylic latex is a unique system with low or no VOC, so can be used as a 'green coating' system where colour and good durability are required. This system

was used when the iconic Golden Gate Bridge in San Francisco was repainted in the 1980s. If this system is specified, as well as all the other concerns regarding drying, curing and topcoating, it is essential that there is no residual alkalinity on the surface. Investigations by the US Department of Transport (16) showed acrylic topcoats inevitably blistered over WB-IZS within 60 days, unless the primer was subject to cyclic wetting and drying before topcoat application. This created a neutral pH surface. The only other method for neutralising the surface was application of a phosphoric post-cure acid wash, an unlikely activity by coating applicators. Pressure washing was not sufficient to create a neutral surface. These researchers recommended testing the pH of the surface to ensure it is between 4 and 7 if it is to be over-coated. This is in addition to checking that the coating is thoroughly cured. Unfortunately, standardised tests are not available for either of these requirements, although ASTM D4262 (17) can be easily adapted for pH testing and Riding (18) has developed a method for testing cure of the WB-IZS coatings.

Fact: IZS can be successfully topcoated, but the applicator must be especially careful regarding proper curing, absence of surface contamination, special application techniques to avoid topcoat bubbling and, with the WB product, a pH neutral surface. It is not a simple activity.

CONCLUSIONS

Inorganic zinc silicate, whether solvent-borne or water-borne, provides a number of unique challenges for the specifier and applicator. However, the excellent protection provided by these systems, along with its rapid application and good economy mean that it is worth learning to properly apply it and understand its limits and idiosyncrasies. The asset owner will be rewarded by successful application of this important product in the fight against corrosion.

REFERENCES

References marked * are included in “*Inorganic Zinc Coatings – History, Chemistry, Properties, Applications and Alternatives*”, edited R A Francis, ACA publication ACA-1 (2013).

- 1 *A Thomas, Water-borne Silicates in Coatings and Construction Chemicals, Surface Coatings Australia, March 2009, p10 and April 2009, p14.
- 2 *I Baxter, Corrosion Australasia, Vol 18, No. 2, pp 11-12, (April 1993).
- 3 *K Lofhelm, E Hemmings and A Szokolik, Corrosion & Prevention 2006, Hobart, Tasmania, 2006, Paper 003.
- 4 E Hemmings, Personal Communication, March 2001.
- 5 *R A Francis and A Szokolik, Corrosion & Prevention 2000, Auckland, New Zealand, 2000, Paper 071.
- 6 *E Hemmings and N Demirdjian, Corrosion and Prevention 2001, Newcastle, New South Wales, 2001, Paper 088.
- 7 *F Salome, Corrosion and Prevention 2002, Adelaide, South Australia, 2002, Paper 017.
- 8 W Mandeno, Private communication. (2013).
- 9 *R Francis, D Ellis and A Walker, ACA ‘Corrosion Control 007’ Conference Proceedings, Sydney (2007), republished in Corrosion & Materials, June 2008, pgs. 30-37.
- 10 *J Zhang and A L Walker, Proceedings, Austroads 8th Bridge Conference: Sustainable Bridges - The Thread of Society, Sydney, Australia, 2011.
- 11 *E. Riding “Inorganic Zinc Silicate Coatings - Chemistry and Protective Properties”, Inorganic Zinc Seminar, Melbourne, 1997, ACA.
- 12 W J Paton, “Performance characteristics of zinc-rich coatings applied to carbon steel”, NASA Technical Note D-7336, (July 1973).
- 13 R Freedman, Private communication (2013).
- 14 K B Tator, “Topcoating Zinc-Rich Primers”, Materials Performance, March 1976, pgs 9 – 16.
- 15 SSPC-PS Guide 8.00, Guide to Topcoating Zinc-Rich Primers (2002).
- 16 J P Ault, C L Farschon, “Adhesion criteria between water-based inorganic zinc coatings and their topcoats for steel”, FHWA-RD-98-170 (March 1999).
- 17 ASTM D4262, “Standard Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces”, ASTM International, West Conshohocken, PA, USA.
- 18 *E Riding, “Field Test for Water Insolubility of Water Borne Inorganic Zinc Coatings”, Jotun General Information Bulletin No 002, Revision 1. Issued July 2002.

AUTHOR DETAILS



Rob Francis is a metallurgist and a corrosion and coatings specialist. He has over 40 years experience in metals, materials and corrosion, especially regarding protective coatings. Dr. Francis obtained a B.Sc. in metallurgy from the University of Melbourne and has a Ph.D. in corrosion science from the Corrosion and Protection Centre at the University of Manchester, UK. He is an Australasian Corrosion Association Corrosion Technologist and Coating Inspector, a NACE Certified Coating Inspector and is Chairman of MT14/2, which has developed AS/NZS 2312 on the selection and application of protective coatings. He edited the recently-released revision of the ACA publication *“Inorganic Zinc Coatings – History, Chemistry, Properties, Applications and Alternatives”*