

An Edge Retentive Coating Solution Based on a Tolerant, Solvent-Free Epoxy System

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Introduction

Whenever a coating scheme is specified for the corrosion protection of a steel structure, there are some key points to consider during application, in order to achieve the performance of the coating system and hence the success of the original specification. The thickness of the applied coatings is one of those vital concerns. Another important key point is the surface preparation, which should meet the requirements of the coating material.

From the above, it is clear that the specified coating thickness should be kept constant all over the surface to be coated. However, during curing, coatings shrink and pull away from sharp edges and weld seams. This effect leads to a situation where the final dry film thickness (dft) at the edges is lower than the thickness deposited on the surrounding flat surfaces. Since this effect of shrinking and pulling away from edges is different for different types of coatings, a new coating property must be defined: the Edge Retention Ratio (ERR). ERR can be defined by the following equation:

$$ERR = \frac{\text{dft (edge)}}{\text{dft (flat)}} \times 100$$

Poor edge retention will cause sharp edges to be vulnerable to corrosion and to mechanical damage (and subsequent corrosion). This localised corrosion is a starting point for the spread of corrosion, which produces substantial early coating failure.

Any solution to avoid poor edge retention should also consider the common concerns during application, such as dew-point restrictions, or new ones, like surface preparation technologies using water (e.g., ultra high pressure {UHP} hydroblasting).

This article presents a scheme utilising two coats of an edge-retentive epoxy, where the second coat addresses the edge-retention problem, and the first coat

assures outstanding surface tolerance, not only to corrosion, but also to moisture (no dew-point restrictions).

Consequence of Poor Edge Retention

The early corrosion process caused by the lack of coating thickness is related to the way coatings protect steel from corrosion. There are several mechanisms by which coatings

protect steel, two of them being related to film thickness: physical barrier and electrolytic resistance. Lower thickness means a less imposing physical barrier to the steel, easing the access of chemicals, such as water, oxygen, and salts, which are responsible for the corrosion process. The decrease in thickness will also lower the electrolytic resistance through the film, which helps the corrosion cell to work, meaning that corrosion will progress easily.

The poor edge retention can also be observed in weld seams. The corrosion in weld seams may lead, apart from the loss of steel, to serious structural problems, so a small localised corroded area can be responsible for a large problem.

Coatings on sharp edges, in many cases, are more exposed to mechanical damage: impact and wear from abrasion. If thickness drops, the edges will be more vulnerable to mechanical damage, and subsequently, to the development of corrosion.

Another adverse effect of poor edge retention is the general appearance of an area with numerous corroded sharp edges. The total area that is corroded may be small; however, there may be substantial rust bleeding that contributes to the general unpleasant looking picture. Apart from the shock of seeing such an area, the viewer is confronted with extra difficulty in making a correct assessment of the real extent of corrosion.

How To Solve the Problem

There are two ways to solve the edge retention problem. The classical solution is the grinding of sharp edges or ap-

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Fig. 1: Good edge retention is critical in ballast tanks.

plication of extra coats (stripe coats) in critical areas (sharp edges and weld seams). These option increase the total cost of the job, since more time, paint, and manpower are needed.

The alternative solution is the use of coatings with high edge retention. Such coatings should be specially formulated in order to increase their edge retention ratio, so the thickness at sharp edges will be very close to that on flat areas, after curing.

The authors believe this option to be the most cost-effective and technically acceptable solution, particularly if the new coating scheme is able to complement such a physical behaviour with an excellent intrinsic anticorrosive performance. A combined solvent-free epoxy, double-coat scheme, using two versions of the same product, has proved to be the best answer.

Options for Developing an Edge-Retentive Coating

One detrimental factor for good edge retention is the presence of solvents, which promote the flow of coatings away from edges. The edge retention of some solvent-based epoxy coatings can be as low as 30 percent. Solvent evaporation can be faster at the sharp edges, generating a gradient of density and surface tension between the edge and the flat areas. As result of this, there is a flow of coating away from the edge, giving rise to the low edge retention ratios. Thus, the first option in the development of an edge-retentive coating is use of a solvent-free epoxy formulation as the basis for such a coating. The objective, however, is more ambitious, involving the creation of a two-coat system that provides both surface tolerance and edge retention.

Formulation Parameters

Solvent-free epoxy coatings should exhibit increased edge retention over solvated products. However, even in the absence of solvents, it was found that further progress should be made in terms of edge retention. This may be related to surface tension and rheology.

The paint should have a rheological structure that exhibits a thixotropic behaviour. The paint initially is a thick liquid, but, when small forces are applied, it becomes relatively mobile.

However, when this force is removed, the paint recovers its rheological structure relatively quickly. This fast recovery of rheological structure plays an important role in the edge retention.

The surface tension of a paint also affects the edge retention. Since the edges have a larger area, then the tendency for "pulling" the surface molecules towards the bulk is higher at the edge compared with the adjacent flat areas. This "pulling" will then result in a larger decrease in volume and consequently a greater decrease in film thickness. Since the referred "pulling" effect decreases with surface tension, then a lowering of surface tension should contribute to an improved edge retention.

Taking into account the considerations of rheology and surface tension described above, our company formulated and tested a solvent-free epoxy system for edge retention.

Testing

The behaviour of a new edge retentive, solvent-free epoxy coating was evaluated with the help of cross-section microscopy of coated steel edges. Figure 2 presents a conventional paint behaviour (with poor edge retention), whereas the improved edge retentive behaviour of the solvent-free epoxy can be observed in Figure 3.

The new product achieved edge retention ratios from a minimum of 85 percent to maximum values of 90 percent. The compatibility with the parent primer was complete, as expected.

Table 1: Results of Salt Fog Testing

Properties after 700 hours of salt fog testing (NF ISO 9227)	Requirement of the product according to Annex A6.6 of Booklet 2-59	Paint system	
		Average thickness 306 microns Dry surface	Average thickness 303 microns Wet surface
Visual examination			
•Blistering	None allowed	None	None
•Rusting	None allowed	None	None
•Corrosion creep from scratch	<1	None	None
•Cross-hatch adhesion (ISO 2409)	1	0	1
•Pull-off adhesion (EN 24624)(Mpa)	>1.5	10	9.4
•Zone of disbondment		80 % in finish coat 20 % in primer	85 % in finish coat 15 % in primer

The performance of the parent primer has been verified in our laboratories and also by outside agencies as part of their product approval process. The results of this testing from one company is given below.

SNCF Testing

The full system, epoxy primer and edge retention epoxy, was tested by SNCF (French Railways), who carried out accelerated weathering tests and compared the results to the requirements of paragraph A6.6 of the specification booklet 2-59, relative to the characteristics of a paint system specifically for UHP-prepared surfaces.

The system tested was one coat of solvent-free epoxy primer, one coat of solvent-free (edge retention) epoxy, and one polyurethane finish coat with a total dft of about 300 μm .

The paint system was applied to steel test panels, of which the initial state of the surface was equivalent to at least Sa 2 1/2 and a roughness of "medium grit," Ra 8.4 μm (Ra Sa 2 1/2 = 5.5 μm , Ra Sa 3 = 10.6 μm) and which had the following pre-conditioning:

- Rusting for 16 days in salt fog according to the conditions of ISO 9227 to obtain a rust grade C (ISO 8501-1) followed by
- UHP waterjetting at 1400 bar to obtain bare steel, followed by
- Storage of panels until a degree of flash rusting of OF1 according to the standard NFT35-520 was obtained.

The full system was then applied to both dry and wet test panels as prepared above.

The test panels were subjected to 700 hours of salt fog testing (ISO 9227), after which they were assessed visually and by both cross-hatch and pull-off adhesion tests. The results are given in the table on p. 21. These results confirmed that the system met the requirements, whether the surface was wet or dry.

Oil Company Testing

Product testing of the basic solvent-free epoxy primer for the system was also carried out by a major oil company. Initial pull-off adhesion tests, using a pneumatic adhesion tester (ASTM D-4541, A 2), were carried out on a single coat applied after the following pretreatments: hydroblasting DW-2 (STG-2222 Standard); mechanical cleaning (ST 2 and ST 3, SIS 055900 Standard) with wet and dry surfaces; and slurry blasting. Under all these conditions, the adhesion values were very high, between 17.0 Mpa and 24.0 Mpa.

Based on these results, further testing was carried out on panels prepared by hydroblasting to DW 2 (STG 2222 Standard), with 2 coats of the solvent-free epoxy at 150 μm each applied. Testing included the following:



Fig. 2: Poor edge retention of a conventional coating.



Fig. 3: Improved edge retention of solvent-free epoxy. Photos courtesy of the author.

- Salt spray (ASTM B-117) for 5,000 hours
- 100 percent relative humidity (ASTM D-2247) for 5,000 hours
- Immersion in the following liquids: artificial sea water for 14 months, distilled water at 40 C for 3,000 hours, xylene for 14 months, crude oil for 14 months, diesel fuel for 14 months, NaOH solution of 40 percent w/v for 3,000 hours, and H₂SO₄ solution of 30 percent w/v for 3,000 hours

The results from this testing were very good, with no failures observed on samples without intentional damage. Consequently, field testing was carried out in aggressive conditions, both offshore and in a refinery, leading to the following conclusions about the product:

- easy to apply by airless spray, brush, and roller
- easy to handle, store, and transport (by plane)
- could be applied in severe conditions, such as high humidity, rainy weather, and over less than ideal surface preparation (ST 3)
- achieved cost savings of about 30 percent by using a two-coat system (150 μm each coat) over a hydroblasted surface on an offshore platform
- achieved cost savings of 15 percent and VOC reductions of 100 percent in internal and external coating of storage tanks.

Conclusion

The needs of anticorrosive protection are changing. There are new performance requirements, emergent environmental issues, issues of cost, and increased safety concerns. The development of an edge retentive, solvent-free system that can be applied over wet surfaces, without dew-point restrictions, would appear to address some of these concerns and issues.

Editors Note : This article is an up-dated and extended version of a presentation given at the SSPC 2000 conference.