The synergy between water-borne epoxy and high solids polyurethane legislation compliant coatings

G A Howarth

Introduction

Degraded steel and concrete structures are expensive to rectify. For example, the annual cost of corrosion to America, has been estimated at $50 billion.1 There are a number of methods of corrosion protection, and among them organic coatings are popular due to their relatively low cost and ease of application. They have a market share (corrosion protection) of circa 60%. They are also relatively easy to reapply when the coating is past its useful life. As an example, the Forth rail bridge is continuously coated over a cycle of a few years and is in excellent condition after 115 years despite being in an estuary. The same applies to some of London's bridges.2 Coating steel also reduces the amount of electric current required when cathodic protection is in use.

Recent legislation aimed at improving the environment has concentrated the thinking of resin and coatings formulators. PG6/239(95) and PG6/34(95) published by HMSO gives a number of Volatile Organic Compounds (VOC) figures that coatings must meet to conform to legislation.3 An alternative is to install solvent abatement plant to reduce emissions at source, but this equipment has a very high capital and running costs. Consequently, the R&D objective of most coating and resin producers is the reduction of solvent content of the paint and resin systems by the use of high solids and water-borne materials.4-5 A number of formulators have published papers discussing the use of water-based and low solvent/high solids and hence low VOC, environmentally friendly systems for coating engineering materials.6-8 The epoxy resin and polyurethane industries are no exception.

Legislation compliant epoxies

Two-component epoxy coatings are used in a wide range of applications including the protection of steel from corrosion. In the 1960s water-based epoxy systems were introduced,1-2 which permitted significant reductions in organic solvent content. Significant advances have been made in this technology and its use in anti-corrosion applications since then. There are a number of papers and reviews available.9-20

Usually, epoxy resins are cured by polymers with amine functionality. Amine polymers are hydrophilic and dissolve or disperse in water. Epoxy resins can then be emulsified in the amine polymer solution. A cross-linked polymer is formed by a sequence of chemical cure and particle coalescence. If either the polymeric amine curing agent, also known as the hardener, is pigmented or the epoxy resin, then a paint film is created on curing. The curing of an epoxy with an amine curing agent is illustrated in Figure 1 and a schematic epoxy film formation sequence is shown in...
Focus:

Figure 2. Using pigment in the resin ensures a paint film rather than a polymer film is formed.

Experimental

Preparation of panels for accelerated testing
Cold-rolled 6" x 4" steel panels were degreased, dried at 60°C for 1 minute, cooled, and a 100μ wet film applied with an applicator bar to the panels. The edges and corners were coated by brush. The coated panels were dried at room temperature for 7 days. Duplicate panels were then placed both in a Prohesion™ and a salt spray cabinet. Aluminium panels of 6" x 3" were coated by brush for UV resistance testing.

Accelerated testing

The QUV™ machine was set to give alternative 4 hour exposure to UV-B followed by 4 hours condensation at 50°C. The machine was run continuously. UV-B was used because it is of higher energy and more harmful than sunlight. Thus, this test is very harsh but it does not correlate well with external weathering tests in the UK where UV-A is more appropriate. Primers are not usually tested for UV resistance, normally, it is only the finishing coat. However, some limited UV testing was done on primers. To be really useful, cyclic testing using salt-spray should include UV exposure. Absence of UV light is a major weakness of salt-spray and one of the reasons why it gives spurious successes when a coating would fail in real exposure conditions. Salt-spray and Prohesion testing was carried out according to ASTM methods.21-25 The parameters assessed were blister resistance, creep under scribe, general corrosion rating, drying rate, adhesion, 3 day Persoz hardness. All parameters were rated on a scale of 0–10 where 0 is the worst rating and 10 the best. An overall score was then assigned to each paint based on the sum of the individual 0–10 scores for each category. The maximum score possible is therefore 60.

The parameters examined in the paint development were the resin system, pigmentation including fillers, Pigment Volume Concentration and additives.

Optimisation of pigmentation system

The epoxy hardener was pigmented throughout this work and the volume solids standardised at 50%. Pigmentation systems are extensively reviewed elsewhere.5,20 The most popular non-toxic anti-corrosion pigments in Europe for coatings are the zinc phosphate types. Research has shown that these are not necessarily the most effective, though this varies depending on which accelerated test method is used. Zinc phosphate tends to retard the curing rate of water-based epoxy coatings, which is not desirable, but also lengthens the pot-life, which is usually considered beneficial. This is thought to be due to the zinc being complexed by the amines, which are then not available to react with the epoxy resin. This complexing is illustrated in Figure 3.

In effect most anti-corrosive pigments are inhibitors. Often they work by the rapid release of eg chromates under solubility control, giving a high level of protection but are environmentally unfriendly.26-28 Zinc phosphate has lower toxicity and has a slower release mechanism, but is not really suited to aggressive conditions. The corrosion protection