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Anticorrosive properties of the epoxy–cardanol resin based paints

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Abstract

An epoxy–cardanol resin was developed using epichlorohydrin, bisphenol-A and cardanol. On evaluation it was found that epoxy–cardanol resin exhibits better properties as compared to epoxy resin in terms of increase in tensile strength, elongation, bond with steel and lowering of water vapour transmission of the film. The improvement in these properties indicated that the paints based on modified resin would be more durable than the epoxy based paints. Accordingly, paints were formulated using the developed resin and their performance were compared with their counterparts made with unmodified epoxy resin. Zinc powder, zinc phosphate, micaceous iron oxide and synthetic iron oxide were used as pigments along with fillers, additives and an aromatic polyamine adduct hardener. For both types of paints similar doses of pigments and additives were used. Physico-mechanical properties, chemical resistance and corrosion protection efficiency of the formulated paints were determined. It was found that the anticorrosive properties of epoxy–cardanol resin based paints are superior to that of the paints formulated with the unmodified epoxy resin. Micaceous iron oxide based paints in epoxy–cardanol resin showed the best performance followed by zinc phosphate based paints. It is concluded that the developed resin is a better binder media for the formulation of paints.

Keywords: Epoxy; Cardanol; Pigments; Paints; Permeability; Corrosion; Chemical resistance

1. Introduction

The surveys of corrosion damage in the early 1990s showed that in an industrialized country, 4% of the gross national product (GNP) is lost as a result of corrosion. This figure includes both direct and indirect costs [1]. The survey on causes of corrosion failures has shown that over 40% of the failures are due to improper selection of materials, ineffective design measures and non-use of efficient and durable protective coatings. All these causes of corrosion failure could be avoided. For this purpose newer corrosion resistant materials, better monitoring and detection techniques and technologies for repair and rehabilitation are the need of the hour. To meet these requirements, present investigations are directed towards the development of highly resistant coating system for the protection of steel structures exposed to aggressive environment.

In anti-corrosion coatings, use of epoxy resin dominates over other synthetic resins due to its superior strength, low shrinkage, better bonding with different substrates, good dimensional stability and long term corrosion and chemical resistance [2,3]. These properties have prime importance in the construction and building applications. The ambient curing epoxy systems generally consist of two components—a base component and a curing agent or hardener. The base component is epoxy resin, which is normally a standard liquid epoxy resin DGEBA, diglycidyl ether of bisphenol-A (a condensation product of bisphenol-A and epichlorohydrin). The room temperature curing agents that are generally used with epoxy resin to initiate the cross linking are polyamines, polyamides and their adducts [4,5]. One problem with the coatings made with epoxy resin is that they are rigid and have limited deformability. It does not help in stress relaxation during their service life and may fail due to cracking. To overcome this problem and to achieve other desired properties epoxy resin is often modified with different other polymeric compounds, such as coal tar [6,7], cashew nut shell liquid [8–11], phenolic and other resins [12–14].

In this study, an attempt has been made to modify an epoxy resin with a cardanol resin for improving its physical properties and chemical resistance. The modified resin was synthesized using epichlorohydrin, cardanol and bisphenol-A and designated as epoxy–cardanol resin. Properties of the two resins, epoxy–cardanol and unmodified epoxy, were evaluated by determining their physico-mechanical and chemical resistance properties. Paints were formulated using the developed

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epoxy–cardanol and the unmodified epoxy resins with pigments, additives and aromatic polyamine adduct as a hardener. The developed paints were evaluated for their physico-mechanical properties, chemical resistance and corrosion protection efficiency.

The paper reports the outcome of the study in two parts. The first part relates to the synthesis and evaluation of the modified epoxy resin and the second deals with the formulation and evaluation of the formulated anticorrosion paints.

2. Synthesis and evaluation of resins

2.1. Synthesis of resins

A modified epoxy resin was synthesized using epichlorohydrin, bisphenol-A and cardanol as main raw materials. Glycidyl ether of cardanol was obtained by reacting epichlorohydrin and cardanol, and a prepolymer of epoxy resin DGEBA by reacting epichlorohydrin and bisphenol-A. The reactions were carried out in an inert atmosphere at about 150 °C. The two resins thus obtained were mixed in a predetermined ratio and heated at about 60 °C under controlled conditions. The resin so obtained was designated as epoxy–cardanol resin.

The epoxy equivalent weight of the epoxy–cardanol resin was 210–230, viscosity 5000–6000 mPa S at 25 °C and density 1.05 g/cm^3. The unmodified epoxy resin had an epoxy equivalent weight of 180–200, viscosity 8000–10,000 mPa S at 25 °C and density 1.15 g/cm^3. An aromatic polyamine adduct based hardener was used with these resins. This hardener had an amine value of 320–340, viscosity 3000–5000 mPa S at 25 °C and density 1.10 g/cm^3.

2.2. Preparation of test samples

Mild steel and glass panels of 150 mm × 100 mm size were used and prepared according to the method given in IS: 101 Part 1/Sec. 3: 2001 [15]. The steel panels were made free from oil and grease by cleaning them with xylene and then brushed uniformly with an emery cloth of IS Grit No. 180. Traces of emery dust were removed by wiping with a linen rag and swapped with a linen rag pre-soaked in a hydrocarbon solvent to degrease the panels. Then the panels were dried to remove the traces of condensed moisture. The glass panels were degreased and dried in a similar way. Two coats of each resin were applied on the thoroughly cleaned steel and glass panels using a paintbrush. The coated panels were left in the laboratory for 7 days to ensure full drying and curing of the films. The edges of the steel panels were then sealed with wax to prevent attack from the edges. At least three steel panels were prepared for each chemical resistance and humidity cabinet test. To obtain free film properties, the films were carefully removed from the coated glass panels.

2.3. Testing of the coatings

Free film properties of the coatings, such as tensile strength, elongation and water vapour transmission were measured as per ASTM-D-2370-1992 [16] and ASTM-D-1653-1993 [17]. Bond strength was measured by the pull out method as per BS: 3900-E-10-1979 [18] using a Dyna Proceq adhesion tester, while scratch hardness and adhesion and flexibility were determined using the coated steel panels according to the method given in IS: 101 Part 5/Secs. 1 and 2: 1988 [19].

Table 1
Properties of the epoxy and the epoxy–cardanol coatings

Property	Epoxy–cardanol	Epoxy
Tensile strength (N/mm^2)	21.5	16.4
Elongation (%)	16.5	7.2
Specific permeability (mg/(cm^2 mm 24 h))	0.140	0.214
Hardness, Shore D	83.0	85.0
Shear strength (N/mm^2)	7.70	5.86
Vicat softening point (°C)	64.0	43.0
Adhesion (bond strength) with steel (N/mm^2)	3.2	2.5
Scratch hardness, 1500 g load	No failure	No failure
Coefficient of thermal expansion (10^{-6} per °C)	8.8	17.1
Scrub resistance, 10,000 cycles	No failure	No failure
Salt spray, 1000 h	No corrosion spots	Few corrosion spots

2.4. Results

Results of the above studies show that the modification of the traditional epoxy resin with a cardanol resin improves properties of the film. For example, tensile strength and elongation are increased while water vapour transmission decreased (Table 1). The coefficient of thermal expansion became comparable with that of the concrete, which is 6.1×10^{-6} to 12.2×10^{-6} per °C [20]. These results indicate that the coating based on the modified resin would be more effective and durable as compared to the epoxy based coating. It means that the modified resin could be a better binder for paints.

3. Formulation and evaluation of paints

3.1. Formulation of paints

Paints were formulated using pigments like synthetic iron oxide, zinc phosphate (ZnP), zinc powder, micaceous iron oxide (MIO), blank fixe, calcite, magnesium silicate and titanium dioxide along with other additives and solvents. Epoxy–cardanol resin with the aromatic polyamine adduct based hardener and unmodified epoxy resin with the same hardener were used as binders. The pigment volume concentration of the paints was kept at about 25% except that of the zinc powder based paints for which it was 70%. The compositions of various paint formulations used are given in Table 2.

3.2. Preparation of the test samples

Mild steel and glass panels were prepared as discussed in Section 2.2 above. The panels thus prepared were coated with the developed paints for carrying out laboratory tests. Two coats