Epoxy Finishes for Corrosion Control

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One of the earliest applications of epoxy resins which even today absorbs almost 50% of their production is chemical resistant surface coatings. Today they are employed in the form of solvent-containing and solvent-free coatings, mortars, and glass reinforced linings. In these applications, epoxy resins exhibit not only outstanding chemical resistance, but very good mechanical strength and fairly good resistance to heat.

PROCESSING OF EPOXY RESINS

The resins usually employed are condensates of epichlorohydrin and Bisphenol A and can be either solid or liquid. Table I below gives the typical properties of liquid resins :

Table I

Some typical properties of liquid resins

Epoxy Equivalent	Viscosity	Specific Gravity at 25°C
180—194	8000—12000 cP	1.171
232—244	1200— 1600 cP	1.140
175—200	550— 650 cP	1.175
400—455	2000— 5000 cP	1.13

Hardeners or Curing Agents

Hardeners commonly used are aliphatic amines, polyamides or amine adducts. The type of hardener used strongly influences the properties of the cured resin. Thus, if a polyamine hardener is used with an unmodified resin, a rather brittle product results which has rather poor adhesion to most materials whereas polyamide hardeners yield flexible products with very good bonding properties even though their resistance to water and chemicals may not be quite as good. Adducts yield films having similar properties as those obtained with amines, but they usually have a low dermatitis potential and some can be used even in the presence of moisture.

Polysulphides are rarely employed. In some cases accelerators can be used to hasten curing. Recent developments have made possible the blending of two different hardeners to produce stable mixtures. By varying the ratios of the two hardeners, tack-free time can be varied from about 21 hours at 20°C to about 4 hours at 20°C.

Additives

Unmodified resin/hardener systems are very rarely used. Various additives are usually incorporated to obtain certain desired properties. Plasticizers of different kinds are often pre-mixed in the resin to impart good flexibility or resilience.

Thixotropic agents are used to prevent coatings from flowing off vertical surfaces. Reactive diluents are sometimes blended with the resin to reduce its viscosity. Colouring pastes or pigments are added to obtain any desired shade of colour. Fillers like silica flour, quartz sand and bauxite are very frequently employed not only to reduce the cost of the resin but also to improve its mechanical properties, like abrasion resistance and compressive strength and to alter its thermal properties like conductivity and coefficient of expansion.

Finally certain additives like coal tar may be mixed in to reduce the cost, even though they impair to some extent some of the properties.

The ease with which epoxies can be modified make it possible to adjust the properties of the cured resin within very wide limits. Thus, it is possible to have a 'tairlor-made' product for a number of different applications. The remarkable versatility of epoxies has rendered them particularly suitable for the repair of concrete and for the protection of different surfaces against corrosion.

TYPES OF COATINGS

Solvent-free Coatings

The phenomenon of corrosion can be explained in terms of short circuited galvanic cells on the metal surface. Such cells are set up because of differences in the environment. One of the ways by which corrosion can be prevented is by giving a protective coating to slow down the rate of diffusion of oxygen. Of a number of factors which are decisive for the quality of organic protective coatings, the film thickness is of the greatest importance. Although this fact was known qualitatively to the paint chemists for quite some time, it was only in 1954 that Tator published material which numerically verified the immense importance of the layer thickness. Tator proved that only coatings of a thickness of more than 0.13 mm (5 mils) could be used in protection from heavy corrosion.

If using a solvent containing paint, even one of the highest possible solid content, this requirement could only be satisfied by a three layer structure.

Should the required thickness of the coating be even greater, the number of layers will grow accordingly. This is the case, for instance, with coatings exposed to great mechanical and chemical stresses. Epoxy coatings based on ARALDITE resins can be solvent-containing or solvent-free. Solvent—containing systems are found suitable as general purpose corrosion resistant coatings. However, if the conditions of corrosion are more severe, the choice of solvent-free coatings is an ideal one.

Solvent-free systems based on liquid epoxy resins have the following advantages :

— their viscosity is low enough to enable them to be applied at room temperature by the usual techniques

— they cure practically without shrinkage and without giving off volatiles, resulting in dense coatings with excellent mechanical qualities and chemical resistance with almost no interior stresses

— they adhere well to steel and concrete

— they distinguish themselves by excellent electrical insulating qualities.

In addition to this, these coatings offer the great advantage of higher security during application by eliminating the threat of explosions and danger to the health of personnel because of the absence of solvent vapurs.

Advantages of solvent-free coatings have been recognised at an early date and number of useful systems have been developed after years of basic research. Table II gives the chemical resistance of a typical solvent-free epoxy coating.

Table II

ARALDITE GY 250 : HY 830 : HY 850 = 100 : 30 : 30

Acetic acid 10%	R	Nitric acid 10%	8*
Acetic acid 100%	F	Paper bleach liquor	F
Acetone	F	Petroleum	R
Ammonia 10%	R	Phosphoric acid 4%	R
Ammonia conc.	R	Phosphoric acid 10%	R
Butyl alcohol	3*	Phosphoric acid 43%	18*
Chloro-acetyl chloride	F	Sea water, synth.	R
Crude oil/fuel oil	R	Sodium Hydroxide 5%	R
Deionized water	R	Sodium Hydroxide 30%	R
Diacetone alcohol	1*	Sodium Hydroxide 50% at 60°C	6*
Edible oil	R	Sodium chloride solution 2%	R
Epichlorohydrin	F	Sodium chloride solution 20%	R
Ether	F	Sulphuric acid 3%	R
Ethyl alcohol 50%	R	Sulphuric acid 10%	R
Ethyl alcohol 95%	F	Sulphuric acid 20%	R
Ethyl acetate	1*	Sulphuric acid 30%	R
Heptane/Toluene 25 : 75	3*	Sulphuric acid 40%	R
Heptane/Toluene 50 : 50	R	Sulphuric acid 50%	F
Heptane/Toluene 75 : 25	R	Sulphuric acid 60%	F
Hydrogen peroxide 40%	3*	Sulphuric acid 70%	F
Hydrochloric acid 10%	R	Sulphite waste liquor	R
Hydrochloric acid conc.	3*	Sulphite waste liquor at 50°C	6
Isopropyl alcohol	1*	Sulphite waste liquor at 90°C	1
Javelle water	3*	Tetraethyl lead fuel	R
Kerosene	R	Trichloroethylene	F
Methyl ethyl ketone	F	Toluene	2*
Nitric acid 3%	9*	Xylene	2*

R = Resistant (unaffected after two years exposure)
* = Limited resistance (Figure denotes months)
F = Failed.

Coal Tar/Epoxy Combinations

Some derivatives of tar are, because of their low price, most interesting modifiers for epoxy resins. The addition of certain types of tars improves the resistance to water, aqueous solutions of acids, and often also the adhesion of the coating to the substrate—thanks to better wetting properties.

The main fields of application are protective coatings in the chemical industry, the building of waterways, water-purification plants and sewers.

Epoxy Mortar

Being highly resistant to many chemicals and to abrasion, epoxy resins are excellent materials for screeds for flooring. A solvent-free formulation is now available for use with sand which gives a hard floor with exceptional resistance to a wide range of chemicals, particularly inorganic acids and alkalies. Screeds made with epoxies are easy to lay and they are sufficiently hard to allow people to walk over the floor within 24 hours. When fully cured they are stronger than concrete. A comparison is made as under :

	Concrete PC 300	*Epoxy Mortar Filler : Binder = 6 : 1*
Unit weight	2.4 tonnes/m^3	2.1 tonnes/m^2
Compressive strength	400 kg/cm^2	1000 kg/cm^2
Tensile strength	60 kg/cm^2	400 kg/cm^2
Modulus of elasticity	300,000 kg/cm^2	160,000 kg/cm^2

The epoxy mortar is formulated by incorporating a suitable filler to the resin/hardener mix. Although any inert filler could be used, quartz sand is most commonly used.

APPLICATIONS

Under-Water applications

There are specially formulated solvent-free coatings which can be applied under water. This is of special interest for repair jobs on constantly immersed objects. Because of the difference in wetting properties of steel and concrete, different formulations should be used for each of these substrates, if optimal properties of the cured coating are to be obtained.

Pretreatment of the substrate

Steel substrates should, wherever possible, be roughened by sandblasting. This is especially important in all cases where the cured coating would be exposed to continuous stress by immersion. In cases where sandblasting is not practicable, primers with specially good adhesive qualities and of a certain flexibility are recommended.

The concrete substrate is more complicated since formidable differences in moisture content have to be taken into account. For dry concrete, special treatment with a primer is generally not necessary—solely in the case of a cement rendering plaster which is not very dense a preimpregnation with a low viscous, unpigmented or low pigmented resin/hardener system is advantageous. If still wet, concrete may be coated primarily with an epoxy resin dispersion in water. However, a way of escape must be provided for the residual water in the concrete. If not, blisters caused by the vapour pressure of the entrapped moisture will inevitably be formed on the surface of the cured coating.

APPLICATION TECHNIQUES

Solvent-free coatings

It is a well known fact that the economy of a coating system depends not only on the price of the materials but also a great deal on the cost of the application.

Manual application with a brush or doctor's knife is practised mainly in those cases where the job is so small that a transport of applicational apparatus is not economical or where the parts to be painted are of a very complicated shape.

The one-component apparatus, e.g., one using the airless-principle is a compromise between application by hand and the two-component spraying apparatus, which is at the time being expensive. With the one-component spraying apparatus, the ingredients are pre-mixed in relatively small batches and sprayed. Because of the limited usable life of the mix, this method of application involves careful planning. However, if the work team is well trained, this method can be very practical. The two-component spraying apparatus with its high capacity (up to 500 m^2/hr) and ease of handling (the job can be interrupted at any given moment and for any period of time) are by far the most practical application devices.

The most popular two-component spraying apparatus in Europe is at the moment the SIMGEL of Secmer, Grenoble, France. The mixing of the prewarmed components and their atomisation is induced by the use of compressed air. The apparatus is insensitive to rough handling and has proved itself well in practice. This Company manufactures spray guns based on the airless-principle.

Epoxy Mortar

The epoxy screed is laid by the ordinary builder's method. Small areas can be laid by means of a trowel or float. For larger areas a power driven vibrating tamper gives excellent results.

For maximum mechanical and chemical resistance, the screed should be consolidated as much as possible. Even hand tampering will assist greatly in this respect.

Case Histories

Being highly resistant to different chemicals, epoxies have found useful applications in many industries. A few applications are cited below :

Water Works and Purification Plants

(Lining of containers of all types as well as of pipes, for protection and to facilitate cleansing)

(*i*) High Zone—reservoir in Switzerland. Walls, floor, ceiling and stairs have been coated.

(*ii*) Post-Sedimentation basin of a Sewerage Plant in Switzerland, coated with a solvent-free expoxy resin coating.

(*iii*) Waste Water Purification Plant—for internal coatings on concrete pipes (Brussels).

(*iv*) Sewage purification—internal coatings on filters and tanks. Due to their glassy surface, these coatings are highly suitable for concrete sewage plants. Algae take a firm hold on unprotected concrete and are practically impossible to remove.

(*v*) Effluent Purification Plant—Concrete tanks.

In India, an interesting application of these resins is for the protection of high tensile wires used in the construction of a modern hangar. It was feared that these wires would come in contact with sulphates and chlorides present in the soil. Hence protection was necessary.

COST

(*a*) A solvent-free epoxy coating would cost Rs. 14/- per sq. metre when applied to a thickness of 200 microns.

(*b*) A solvent-free coal tar/epoxy coating would cost Rs. 8/- per sq. metre when applied to a thickness of 200 microns.

(*c*) An epoxy mortar would cost approx. Rs. 70/- per sq. metre when laid to a thickness of 5 mm.

The above prices are the costs of materials only.

References

1. Dr. H. A. Monteiro—Solvent-free Epoxy Coatings

2. Dr. Th. Hirschi—Epoxy Resin Coatings for protection against corrosion.

DISCUSSION

MR. F. A. ATTARWALA (Bombay Municipal Corporation. Bombay)

We have two very old 72" diameter steel pipe lines of about 40 miles in length. Now the carrying capacity of these mains has fallen because of the fall in the value of 'C'. An organisation suggests that we should centre line it. I would like to have some information on this centre-lining. I suppose that it can be done on pipelines which are underground though in our case the pipelines are above the ground.

1. I would like to know by centre lining of this pipeline what would happen to the expansion joint?

2. Whether lining to be done would mean a uniform internal temperature?

3. If we eliminate the expansion joints and provide the centre lining of this pipeline what happens to the lining during repairs.

4. While doing the centre-lining is there to be any temperature control? Whether it is to be at a particular temperature because temperature will be varying from day to night. In the day it may be 130°F and at night time it may be 70°F. Whether a constant temperature is to be maintained?

5. Whether such a centre lining is done indigenously.

6. What would be the cost of such centre lining?

PROF. S. J. ARCEIVALA (CPHERI, Nagpur)

With regard to the agency which does such centre lining process, to the best of my knowledge, there is none at the time, although Indian Hume Pipe Company may do something in this regard. Our Institute had some correspondence with them and some time ago we offered to develop a machine in collaboration with them so that this kind of linging could be done in India.

MR. V. T. PUROHIT (Electro Corr-Damp, Bombay)

If we can develop coal-tar epoxy lining machine then the internal corrosion problem can be solved to a considerable extent.

DR. A. K. LAHIRI (Corrosion Advisory Bureau, Jamshedpur)

Mr. Patwardhan has dealt in detail with problem of water inhibitors.

Regarding the potable water supply, I think sodium silicate has been found of considerable help in reducing corrosion. It has been observed that 5-10 ppm of glassy sodium silicate addition considerably reduces the trouble of the red water and the formation of crust on the surface of the pipe. One advantage of sodium silicate is that it can considerably reduce the corrosion of galvanised pipes also. Such a treatment can be used economically in large apartment or office buildings.

Regarding the epoxy paints, it is important that during the curing, proper ventilation is kept. In a closed system, unless proper care is taken in curing, the epoxy does not function satisfactorily.

MR. K. R. BULUSU (CPHERI, Nagpur)

All industrial waters contain silica (upto 56 mg/l in the form of orthosilicic acid). Now what is the concentration of silica which is required for inhibition. Do we have to add more than the existing 56mg/l. If we have to add more, then the extent of that silica may not remain in solution and may go out.

DR. A. K. LAHIRI (Corrosion Advisory Bureau, Jamshedpur)

It is not the silica as such but the glassy sodium silicate which is effective as inhibitor. The recommended ratio of sodium oxide and silica is 1:2 for the waters with pH less than 6.

DR. K. S. RAJAGOPALAN (CECRI, Karaikudi)

Apart from the quality of calgon in preventing scale formation, it also acts as a corrosion inhibitor. If you adjust calcium in water to say about 50 ppm, the corrosion rate is brought down. If you keep the calgon concentration constant at 20 ppm and study with respect to calcium concentration then you find that with about 50 ppm of calcium, the corrosion rate is brought down and afterwards it continues to be the same. In my opinion the role of calgon as a corrosion inhibitor requires further study.

MR. V. M. SHIDHAYE (Bombay Municipal Corporation, Bombay)

The Bombay Municipal Corporation has laid mild steel pipelines of larger size for underground mains. We have used only external coatings of 2–2½" thick concrete. But with these we have faced many problems. Sometimes the pipe breaks at the joints as the pipes become very heavy. Further there is problem of corrosion also. Wherever the pipelines are above the ground we coat them with red oxide paint. We tried with coal tar jute wrapping but we have not been successful and after a year or two the protection is lost.

DR. A. K. LAHIRI (Corrosion Advisory Bureau, Jamshedpur)

I think the information was quite interesting but I would like to know the type of internal lining used. The jute which has been used as wrapping material is not very much in use now a days. Instead of reducing the corrosion it may, under certain conditions, increase the attack.

MR. S. G. KRISHNAN (NOCII. Thana)

For inhibition of potable water system the American Public Health Association has recommended the use of zinc sodium glassy-polyphosphate. They recommend a maximum of

5 ppm of zinc mainly from this point of view. The formulation should be made from B.P. grade zinc and B.P. grade phosphoric acid.

We have tried epoxy linings for multifarious corrosion problems. In fact our experience has been that the picture with respect to epoxy is not rosy.

MR. K. S. RAO (CIBA, Bombay)

As regards the performance of epoxy coating it is as much dependant on the quality of the product as on the pretreatment part of it. Unfortunately, in India there are not many firms who have perfected the techniques or who have machinery to do this job. The bad application mainly gives rise to poor performance.

As regards the treatment of demineralised water storage tank, I think epoxies have worked out very well.

DR. M. M. LOTLIKAR (NOCIL, Thana)

Regarding the use of calgon I line to add that for inhibition one is to adjust the calcium content at last twice the phosphate present in water. Phospates acts chemically; it goes in to solution and if enought calcium is not present the reverse phenomenon of corrosion many occur.

Whenever the coatings have been tried even on a laboratory scale, we have found porosity. It is never pore-free. You can use any coating and there will be porosity. We have to talk as engineers or scientists with reference to the limitation in this country and the possibilities. Generally most of the coatings used are at about 60°C. Because of the sweating there is a possibility of the acids going through the coating and through to the surface of the metal.

MR. K. S. RAO (CIBA, Bombay)

It is most important to choose the correct epoxy system. There is an unmodified epoxy and also a modified epoxy. As regards the fibre glass to be used it is important to consider the type of finishes. The coal-tar epoxy resin can withstand temperature of 90°C. I would like to correct Dr. Lotlikar who said about 60°C.

DR. A. M. TRIVEDI (Gujarat University, Ahmedabad)

Water treatment is always with reference to available natural water in the area. The total solids are about 2000 in Ahmedabad area. The water contains considerable amount of bicarbonates. A 12″ dia pipe is reduced to 6″and a 8″ dia pipe was once reduced to 2″ dia due to scale formation. Can we remove this incrustation and even if we can the problem is the most serious one. We have to think in terms of treatment which may differ from place to place. We have also to think in terms of a simple equipment.

MR. K. R. BULUSU (CPHERI, Nagpur)

I would like to make an observation on Dr. Trivedi's problem of 2000 TDS and high concentration of bicarbonates, hardness or alkaline hardness. The growth or incrustation he is getting is a result of super-saturation.

PROF. S. J. ARCEIVALA (CPHERI, Nagpur)

I would like to add some comments on the discussion.

We do not want to use a paint which would give us problem of taste and odour particularly with chlorinated water and this has always exercised the minds of the municipal engineers. They do not want to use coal-tar paints.

Generally, water-treatment removes the natural inhibitors in a water supply and very often it must be your experience as it is ours, the treated water is more corrosive than untreated raw water. You remove colloidal material from it and you make it more corrosive.

When the question of laying long pipelines arises the question also arises as to where to locate the treatment plants.

Could I know if there are any specifications laid down by the Indian Standards Institution for epoxy coatings.

MR. K. S. RAO (CIBA, Bombay)

As far as specifications by ISI, they have already brought out one on epoxy mortar, a year back. For the coatings as such, there has not been any, but they are trying to compile specifications on the basis of the standards of other countries.