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Epoxy Resins and Their Uses in Civil Engineering Works

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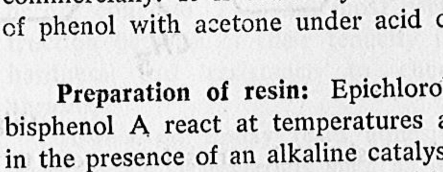
HE epoxy resins are one of the newest type of industrial polymers whose chemistry and plications are developing rapidly. Although ir synthesis has been reported in the 1930's d their manufacture started in 1940's the wth of their importance as industrial resins be traced to the past decade only.

Chemically, epoxy resins, or polyepoxides they are sometimes referred to, are polyers derived structurally from a diphenol or her polyhydric compound and a derivative of hylene oxide. The intermediate epoxy resins pplied by manufacturers are liquids or solids ith molecular weights ranging from a few ndred to a few thousand. The liquid resins e suitable for casting, laminating and potting sins and for solvent-free adhesives, while the lid resins are more adaptable for use as surce coatings. In use, a curing agent is usually nployed to bring about cross-linking or hardning of epoxy resins into an infusible and insoble solid. A three-dimensional network, chacteristic of thermosetting resins is formed, hich contains carbon to carbon and ether linkes. These linkages account for the great rength and chemical stability of epoxy plass. Because of the highly polar nature of the al polymers, they exhibit excellent adhesion a remarkable variety of materials. At the me time the hydroxyl groups present in the lymer are sufficiently separated physically in e molecular net work so that the final proct is not brittle. The high reactivity of terinal epoxy group permits cure of epoxy resins comparatively low temperatures. During cure byproducts are formed, the cross-linking be- effected by a process of addition. This relts in low shrinkage during cure. The interediate epoxy resins have outstanding stability in storage even at fairly high temperatures. Thus they have good shelf life under Indian conditions.

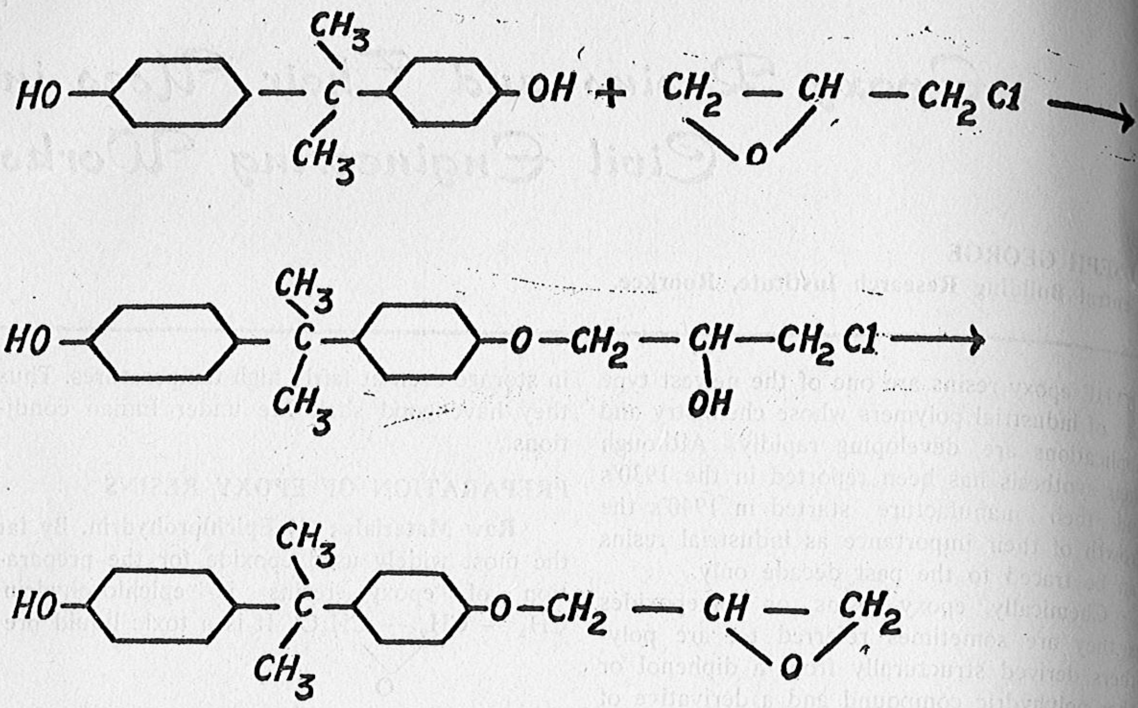
PREPARATION OF EPOXY RESINS

Raw Materials: (1) Epichlorohydrin. By far the most widely used epoxide for the preparation of epoxy resins is epichlorohydrin, $CH_2 - CH_2 - CH_2Cl$ (epoxide ring: the first two carbons bridged by O). It is a toxic liquid prepared commercially as a byproduct of the production of glycerine from petroleum. **(2) Bisphenol A.** Although many dihydric compounds may be condensed with epichlorohydrin to give resinous materials, 2, 2' —bis—(p — hydroxyphenyl) propane,

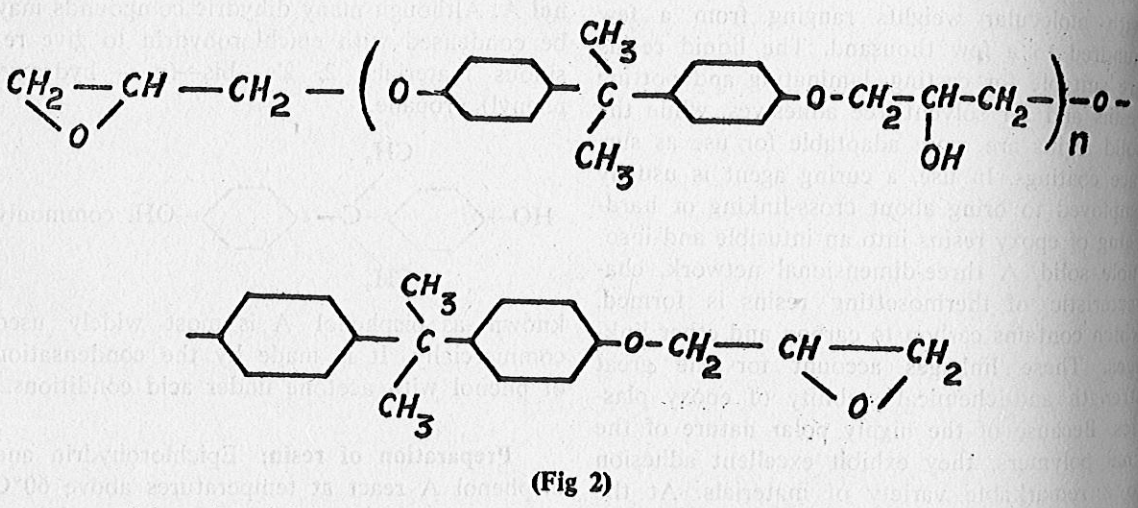


commonly known as bisphenol A is most widely used commercially. It is made by the condensation of phenol with acetone under acid conditions.

Preparation of resin: Epichlorohydrin and bisphenol A react at temperatures above 60°C in the presence of an alkaline catalyst. Addition of the two reagents takes place with simultaneous dehydrochlorination. (See Fig. 1 on page 15). The resulting glycidyl ether further reacts with the dihydric compound, which in turn reacts with more epichlorohydrin to build up a substantially linear polymer. The preparation of the resin is usually carried out with a molecular excess of epichlorohydrin, so that the resulting low polymer has terminal epoxy groups. (Fig. 2).



(Fig. 1)



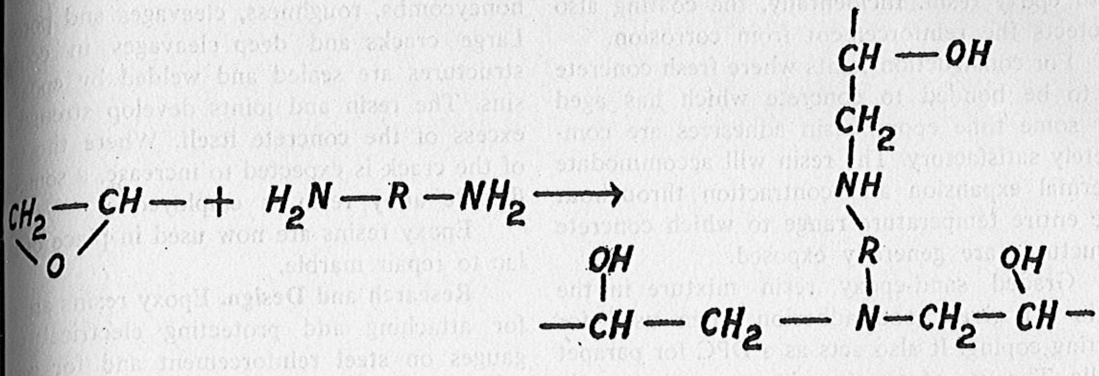
(Fig 2)

In commercial resins 'n' varies from zero to about 20.

CURING OF EPOXY RESINS

It is largely in the three-dimensional cross-linked state that epoxy resins exhibit the outstanding properties of toughness, chemical inertness, flexibility and adhesion in finished products. Conversion of the linear intermediate resins to the three-dimensional polymers may be achieved by reaction with acids, amines or resinous substances such as phenolic, urea and melamine resins. The polyaddition of three chain ends into a cross-linked polymer by a diamine is represented as in the next page (Fig. 3).

Epoxy resins can also be simultaneously cured and modified by blending with compatible thermoplastic or elastomeric substances. The products are what may be called plastic alloys. The wetting properties of the epoxy



(Fig. 3)

oys together with their affinity for a wide riety of materials accounts for their bonding wer. Another property of these alloys is a ro shrinkage factor. They contain no volatile atter and retain their total bulk on harden- g.

SE OF EPOXY RESINS

Flooring. Epoxy resins form an excellent sis for screeds for flooring because of their gh resistance to many chemicals and to abra- on. Used with sand, the screed is easy to lay d sufficiently hard after 24 hours to allow ople to walk over it. By the application of frared lamps, the screed can be set overnight d used for full traffic next morning. When lly cured, the material is stronger than con- ete; the tensile strength is 4 times and the mpressive strength twice as high. In impact rength, a $\frac{1}{4}$ in. epoxy surfacing equals 2 in. ncrete. The dusting, poor chemical resistance, oor impact resistance and wet slipperiness of ncrete floors are overcome by epoxy resin rfacing compounds. For high friction, sand or her grit is added as curing takes place. Non- kid road surfaces, pavements and steps are so prepared in the same manner. Epoxy- arble chip terrazzo flooring is also made in wide range of colours and patterns.

Coatings and finishes. The use of epoxy sins in external decorative and protective atings is increasing. The poor appearance and oor resistance to moisture penetration of cinder d concrete blocks is improved by solventless e-coat epoxy masonry coatings. Pigmented sand-filled epoxy resin coatings for concrete blocks enable plastering and rendering to be dispensed with and produce hygienic easily-cleaned surfaces. Both "mixed-material" and "surface-dressing" techniques are possible. Epoxy coatings ensure protection against the most severe weather conditions. Concrete blocks are also made with a decorative epoxy-aggregate face.

Cold cured epoxy paints are used where high temperatures are not desirable or practi- cable as in tanks, floors, concrete structures, etc. Tests carried out at depths of 900 to 25000 ft. have shown that field applied epoxy resin coat- ings are the best for well castings. Floor var- nishes based on epoxy resins have excellent adhesion and are not slippery. Epoxy resin coatings may be brushed, sprayed, flow-coated, roller-coated or trowelled. They will adhere to ferrous and non-ferrous metals, wood, plastics, glass, leather, rubber, paper, ceramics and wet or dry concrete. They are most useful in cons- truction because of their tenacity in adhesion, hardness and resistance to chemicals and abrasion.

Adhesives. Epoxy resin adhesives bond a wide variety of materials such as wood, metal, glass, ceramics, plastics, rubber, etc. They are therefore used for bonding operations such as setting stone, concrete blocks and tiles; grout- ing bolts and reinforcing rods; setting steel dowels into concrete; attaching precast sections and for anchoring traffic bars to slabs and fitt- ings to walls and doors. The strength of the bond between reinforcing rods and concrete is increased up to five times by coating the rods with epoxy resin. Incidentally, the coating also protects the reinforcement from corrosion.

For construction joints where fresh concrete is to be bonded to concrete which has aged for some time epoxy resin adhesives are completely satisfactory. The resin will accommodate thermal expansion and contraction throughout the entire temperature range to which concrete structures are generally exposed.

Graded sand-epoxy resin mixture in the ratio 6:1 gives good adhesion when used for setting coping. It also acts as a DPC for parapet walls. The use of epoxy resins can permanently lock threaded parts.

Laminates. Laminates made from epoxy resins are characterized by excellent mechanical and electrical properties. Woven glass fibre, paper, textiles, asbestos or metal foil can be used as reinforcing materials. Epoxy-glass cloth laminates have a specific gravity of 1.9 but have practically the same tensile strength as steel. They can be produced at little more than contact pressure. They offer an excellent patching material for metal or ceramic pipes, tanks, vessels, etc. This is of distinct advantage in field repairs.

PATCHING AND REPAIR OF CONCRETE, ETC.

Epoxy resins and in particular some of the resin "alloys" are used in the repair and restoration of concrete construction such as bridges, swimming pools, buildings, roads, basements, sewage plants, dams, silos, stadiums, monuments and other constructions subject to cracks, spalls, honeycombs, roughness, cleavages and porosity. Large cracks and deep cleavages in concrete structures are sealed and welded by epoxy resins. The resin and joints develop strengths in excess of the concrete itself. Where the width of the crack is expected to increase, a somewhat flexible alloy resin is employed.

Epoxy resins are now used in place of shellac to repair marble.

Research and Design. Epoxy resins are used for attaching and protecting electrical strain gauges on steel reinforcement and for general use in concrete.

Casting resins based on epoxies are used for photoelastic studies of structures. They are also used for making models of structures for study in the laboratory.

PRECAUTIONS IN HANDLING

Epoxy resins and particularly their hardeners cause dermatitis in some persons. Care should be taken to avoid contact between the uncured resin and hardeners and the skin. The breathing of the vapours of the hardeners should also be avoided by working in well ventilated areas. Warm soapy water should be used to clean hands and arms after handling epoxy resins.

ACKNOWLEDGEMENT

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