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Soil Burial Tests:

Effect of Soil Burial Exposure on the Properties of Casting Resins

By F. X. VENTRICE

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Styrene-polyester and epoxy casting formulations have been used in the Bell System for over ten years and have a minimum service life requirement of twenty years. The styrene-polyester formulation is a filled phthalic maleic/diethylene glycol ester catalyzed with methyl ethyl ketone peroxide and is by far the most stable and least affected by eight years of soil contact or aging. Two epoxy formulations, unfilled and silica-filled, have the same base diglycidyl ether of bisphenol A resin which is cured with a proprietary epoxy adduct of diethylene triamine. After eight years, unfilled specimens from both burial sites were not significantly degraded but the flexural strength of buried silica-filled specimens was reduced by approximately 40 percent within the first year and then remained relatively constant for the following seven years.

I. INTRODUCTION

Casting resins are thermosetting materials (thermosets) which are hardened by crosslinking at ambient or elevated temperatures. Casting compounds consist of a resin and a hardener or curing agent in one or more parts. The cured plastic can have a wide range of properties by selectively compounding inert additives, such as particulate or fibrous fillers, flexibilizers, colorants, and fire retardants. In production, the two-part formulations are metered, mixed, and finally dispensed into molds or potting containers to encapsulate electronic devices. The encapsulated units may be heated to develop the optimum in physical and electrical properties. Casting resins most commonly used are styrene-polyesters, epoxies, polyurethanes, and silicones.[1] Representative casting formulations used widely in the Bell System, styrene-polyester and epoxy, have been used over ten years and have a minimum service life requirement of twenty years.

II. CHEMISTRY OF CASTING RESINS

2.1 *Styrene-Polyester*

Polyesters are prepared by reacting a polyhydroxy alcohol with a mixture of saturated and unsaturated dibasic acids. The styrene monomer dissolves the polyester resin and reacts with the ester's unsaturated groups to form a crosslinked thermoset. Inhibitors are added to the styrene-polyester to prevent premature gelling. Peroxides are added to overcome the inhibitor action and, finally, to initiate the curing mechanism to form the thermoset. Detailed chemistry of styrene-polyesters appears in numerous references.[2,3]

The proprietary styrene-polyester formulation included in the soil burial program is a phthalic maleic/diethylene glycol ester type which contains 21 percent styrene, 38 percent silica, and 3 percent milled glass fiber. It is catalyzed with methyl ethyl ketone peroxide. Specimens were gelled 45 minutes at 52°C and post-cured one hour at 120°C. Formulation details are listed in Table I.

2.2 *Epoxy*

The conventional epoxy included in this program is a diglycidyl ether of bisphenol A containing 13 percent butyl glycidyl ether as a reactive diluent. It is cured with a proprietary epoxy adduct of diethylene triamine. Chemical reactions of epoxides are detailed in the literature.[4]

The two epoxy formulations are composed of the same base resin and hardener; one formulation contains a fine particle size silica and is tinted with titanium dioxide. Each formulation was gelled at room temperature and post-cured two hours at 85°C. Complete formulations are in Table I.

TABLE I—FORMULATIONS

Material Description	Parts by Weight
Styrene-Polyester	
Fiber glass in silica-filled styrene-polyester	100.0
Methyl ethyl ketone peroxide	1.0
Epoxy	
Diglycidyl ether of bisphenol A containing 13% butyl glycidyl ether resin	100.0
Epoxy adduct of diethylene triamine hardener	20.0
Silica, fine particle size	125.0

III. DISCUSSION OF SOIL BURIAL DATA

3.1 *Styrene-Polyester*

All eight-year specimens, buried and control, prepared from this proprietary formulation retained their original Barcol Hardness of 55, flexural strength, and modulus. Of the three castings buried, the styrene-polyester is by far the most stable and least affected by soil contact or aging (Table II).

3.2 *Epoxies*

The hardnesses, flexural strengths, and moduli of unfilled and silica-filled control specimens remained essentially unchanged over eight

TABLE II—EFFECT OF SOIL BURIAL ON FLEXURAL PROPERTIES OF CASTINGS

Years	Flexural Strength (psi)			Flexural Modulus (psi × 10^{-6})		
	Control	Georgia	New Mexico	Control	Georgia	New Mexico
			Styrene-Polyester			
0	10,400	10,400	10,400	0.860	0.860	0.860
1	12,600	8,400	—	0.980	0.865	—
2	—	12,100	10,400	—	0.830	0.950
4	12,100	11,800	10,300	—	—	0.910
6	—	—	10,100	—	—	0.800
8	9,230	9,550	14,400	0.800	0.830	0.860
			Epoxy			
0	18,700	18,700	18,700	0.540	0.540	0.540
1	19,500	18,300	—	0.570	0.470	—
2	—	18,800	19,600	—	0.510	0.550
4	20,600	18,500	18,000	—	0.560	0.530
6	—	—	17,200	—	—	0.500
8	19,400	17,000	18,000	0.560	0.490	0.500
			Silica-Filled Epoxy			
0	14,100	14,100	14,100	1.100	1.100	1.100
1	12,100	8,500	—	1.200	1.000	—
2	—	9,130	8,790	—	1.000	1.300
4	13,500	8,640	8,700	—	1.300	1.100
6	—	—	—	—	—	1.030
8	11,600	8,190	8,440	1.240	0.960	1.030

years. After eight years, unfilled specimens from both burial sites were not significantly degraded. The Barcol Hardnesses of the unfilled and silica-filled specimens were unaffected by soil contact and remained constant at 35 and 55 respectively.

The flexural strength of buried silica-filled specimens was reduced by approximately 40 percent within the first year of burial and then remained relatively constant for the next seven years as indicated in Table II. Possibly their contact with soil moisture quickly weakens the most vulnerable mechanical bonds between the cured epoxy and silica. The most stable bonds remain unaffected as the flexural strength of the buried specimens fell to a minimum within one year (Table II) and then remained constant.

IV. ENGINEERING IMPLICATIONS

Styrene-polyester and epoxy resins of the type described herein are the basis for many electronic encapsulants. The excellent stability of these casting compositions is dependent on the basic chemical structure of the polymers themselves.

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