

P O L Y M E R C O N C R E T E D E V E L O P M E N T

by

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POLYMER CONCRETE DEVELOPMENT

Approximately eight years ago, a project was initiated at the suggestion of the Bureau of Reclamation to determine the effect of impregnating a cured concrete with a monomer followed by a radiation treatment to cause polymerization. The initial work impregnated concrete bars with gaseous and liquid monomers and used Cobalt 60 gamma radiation. Several remarkable improvements in properties were noted for the samples.

With some refinement in techniques, compressive strengths were increased by a factor of four, tensile strengths by a factor of four, modulus of elasticity was doubled, modulus of rupture was increased by almost four times and water absorption was reduced by a factor of 18. Compressive strengths exceeding 20,000 psi can be obtained.

These results apply to specimens which can be placed in a vacuum chamber to remove pore moisture and can subsequently be impregnated by pressure treatment. Finally, radiation or chemical polymerization must be feasible. For small, precast components this technique is feasible and some practical applications have resulted. Pressure vessels that will take members about 20 feet long and five or six feet in lateral dimension have been built.

In the business of building roads and bridges, we would have very limited application of this type of product. Work is underway to try to develop means of impregnating in-place concrete structures, but without vacuum and pressure, the depth of penetration of the monomer has been very slight. Also, the polymerization of monomers applied to in-place structures poses more difficulty than for precast elements. Polymerization can be accomplished by three techniques. One is by gamma radiation and the early work by Brookhaven National Laboratory concentrated on this method. Polymerization can also be accomplished by using a chemical catalyst and applying

external heat. A third method is to utilize a catalyst and a promoter, causing the reaction to occur at ambient temperatures.

The research that Oregon is involved in is supported by the Federal Highway Administration and its purpose is to develop polymer concretes, as opposed to polymer impregnated concretes. In polymer concrete, the plastic is used as the total binder, without portland cement and water. Portland cement is sometimes used as a filler to improve aggregate gradation, but any similar sized granular material would work as well. Interest in this development is fostered to a major extent by the need for a high strength, quick setting material for structural overlays on bridge decks. Extended closure, or even brief closure, of many bridges causes intolerable congestion and delay to traffic as you are well aware. The polymer concretes can develop adequate strengths in a few hours to carry normal traffic.

Our work to date has involved working with aggregate gradations to minimize the voids and with different combinations of monomers, catalysts and promoters to achieve suitable strengths and workability. At present, tests are being made to evaluate the bond strength between cured concrete and the polymer concrete overlay for different polymers and for different preparatory treatments of the concrete surface. Future tests will evaluate thermal expansion, modulus of elasticity, and shrinkage characteristics of selected mixes.

Compressive strengths in the range of 5,000 psi to 9,000 psi have been obtained for several combinations of polymers. Most of the tests were after 48 hours curing, but very nearly the same strength would be obtained in four to six hours, or even less. Combinations of polymers used include MMA, (Methyl methacrylate) and TMPTMA (Trimethylolpropane trimethacrylate) with a Benzoyl peroxide catalyst and di Methyl aniline promoter. Not many of us are involved enough in chemistry to gain much from words like these. It might be helpful to know that "Plexiglas" is

essentially polymerized methyl methacrylate so we are using products like "Plexiglas" as a binder for the concrete. Another combination of monomers was of polyester and styrene with MEK peroxide as a catalyst and cobalt naphthalene as a promoter. Use has generally been made of a silane bonding agent which provides a chemical bond between aggregate and polymer in addition to the mechanical bond.

The viscosities of the various monomers are generally low. Some are less than one centipoise, making them more fluid than water. This high fluidity poses a problem in that the monomer tends to drain off of the surface aggregate before polymerization occurs. To increase the viscosity of the fluid we have added "Bentone", a modified bentonite used to thicken some paints and coatings. Several satisfactory mixes have resulted; that is, mixes having an appearance of adequate coating without surface flooding and the resulting slipperiness. Some evaluation of surface abrasion and skid resistance is desirable, but we have not progressed that far yet.

To consider a little more detail on the mixes that seem most favorable at this time, we are using one-half inch minus aggregate of natural gravel. To reduce the void content, about six or eight percent cement has been used in a number of mixes. Actually, we found minimum voids when 14 percent cement was used as a filler, but the difference in voids between six percent and 14 percent was slight. The 14 percent cement provided excessive surface area to be coated and the mixes were too dry. Some work has been done on gap graded aggregates, again in an attempt to reduce the void volume. Minimum voids of 18 percent were obtained, a trifle lower than for the uniformly graded aggregate with cement filler, but not low enough to appear economical to separate and reblend the material.

Also, work has been done on crushed aggregates to find the optimum gradation for minimum voids. The interest in crushed material is that skid resistance is likely

to be improved; however, the void volume is higher than for the uncrushed gravels.

Monomer contents ranging from eight to 14 percent have produced mixes having compressive strengths from 3,200 psi to over 10,000 psi. With a good aggregate gradation and eight percent monomer, a 6,000 psi strength was obtained. The 10,000 psi range results from using 14 percent of a polyester-styrene blend monomer. Because of the high cost of the binder, work is concentrating on the lower range of practical monomer contents. For the applications envisioned, 5,000 psi strengths would be entirely adequate providing the bond and abrasion resistance is all right.

The monomers available for this type of product range in cost from roughly \$0.20 per pound to \$1.00 per pound. To be economically feasible, it is necessary to reduce the polymer content as much as possible. To date, our most favorable aggregate combinations require about ten percent polymer by weight. The cost of polymer in a cubic yard of concrete would then be in the range of \$70 to \$350 per cubic yard. To gain satisfactory polymerization, a blend utilizing some of the more costly monomers seems necessary so the \$70 figure is low. A more likely minimum might be about \$110 for the polymer in a cubic yard of mix. Obviously, this must be viewed as a special purpose product whose use might be justified on the basis of the rapid curing and high strength. Where lane closures are particularly crucial, it would have some practical applications as a structural overlay or as a patching material.

Use of the material will depend on a number of factors yet to be evaluated. Bond of the overlay to the old concrete is probably the major problem with most of the overlay materials in use or proposed for use. Some limited research indicates good bond with the polymer concrete, but this has yet to be proven for field conditions under varying moisture and surface contamination of the substrate. Thermal compatibility with concrete needs evaluation. The thermal expansion of most epoxies and some other

plastics is very high, but some of the polymers are similar to concrete. The blend of monomers to achieve suitable characteristics needs study. Mixing and placing techniques for placement of large quantities have yet to be developed. One similar product has been placed with a paving machine and that is our goal.

Curing depends on the heat generated by the reaction between the catalyst and the promoter so it is affected some by ambient temperatures and by the mass of material being mixed. Large quantities react more quickly than small laboratory mixes. This complicates the identification of mixes suitable for field placement. If too little catalyst and promoter is used, polymerization requires the application of external heat. If too much is used, it can set up in the mixer.

The principal objective in studying polymer concrete is to evaluate its potential as an overlay for bridge decks that are excessively flexible and need stiffening in addition to a protective wearing course. At present, we have more questions than answers, but in the months ahead we hope to develop mixes suitable for field placement.