# POLYMER CONCRETE AND ITS POTENTIAL IN THE CONSTRUCTION INDUSTRY

**Luke M. Snell,[1] H. Aldridge Gillespie, and Robert Y. Nelson**

Department of Civil Engineering, West Virginia University, Morgantown, West Virginia, and School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, Oklahoma

**The use of polymer concrete as a building material could represent savings in both materials and labor cost. Development of polymer concrete has not advanced to the degree of widespread commercial application, but, as research produces improved techniques and better monomers, polymer concrete should be at the core of significant advances in concrete construction.**

Concrete, one of our most popular building materials, is relatively inexpensive and easily shaped into various forms. Plain concrete has many desirable properties but it also has many limitations. Its low tensile strength, poor durability (resistance to freeze-thaw), and susceptibility to sulfate and acid attack has limited its use. These problems have been solved for some applications. Concrete has been reinforced with inbedded steel in areas of tensile forces. Air-entraining agents have been used when the concrete had to resist severe freezing and thawing. Special cements have been developed for concrete subjected to sulfate attack and protective coatings placed on concrete exposed to acids. Each of the preceding treatments attempted to improve concrete and did, in fact, provide a solution to a particular problem. However, there has been no single solution which would improve or solve all four major problem areas. Since 1966, a new approach has been studied and it shows great promise of vastly improving the properties of concrete by the formation of a composite material, "polymer concrete" (1).

The idea of polymer concrete came from studies in the wood industry which resulted in the formation of "polymer wood" (2). The technique for forming polymer wood involves impregnating the wood with a particular simple plastic monomer and exciting the monomer to form a complex plastic or polymer. Unlike the formation of polymer wood, there exist two possible methods for the formation of polymer concrete. These are (a) to premix the plastic with the fresh concrete or (b) to impregnate the hardened concrete.

Polymerization involves the conversion of many simple molecules (monomers) into a high molecular weight material. The process consists of a series of stepwise reactions in which the monomers link and often cross link to form the polymer. Chemical catalysts, ionizing radiation, heat, or infrared or microwave energy can be used to activate these reactions (3). This leads to eight possible methods of making polymer concrete, namely to premix the monomer in the fresh concrete or to impregnate the hardened concrete with the monomer and in each case to use one of the above four means to perform the polymerization. Research is almost completely lacking in the use of microwave energy and only limited success has been achieved using chemical catalysts, to convert the monomer in the concrete.

The term polymer concrete is ambiguous since many different materials could be referred to by the same name. In this paper polymer concrete refers to Portland cement concrete, mixed or impregnated with plastics (monomers), and thence polymerized.

A petrographic examination of a polymer concrete, which had significant increase in compressive strength over plain concrete, showed that the polymer was not uniformly dispersed throughout the cross-section of the concrete (4). The polymer was located principally in the cement paste matrix, which indicated that the polymer acts as a binding agent, as does the cement paste. Since the tensile strength of this particular polymer was greater than that of the paste, the polymer probably makes the

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[1] Dept. Civil Engineering, West Virginia University, Morgantown, W. Va.

Proc. Okla. Acad. Sci. 52: 160-162 (1972)

paste matrix continuous and also acts as a crack extension inhibitor.

## PREMIXING OF THE MONOMER

Premixing the monomer with the fresh concrete involves the use of a water-base monomer or the complete substitution of water by the monomer. Since the latter does not form a product of Portland cement concrete it is not here considered further. The best results to date with premixing have been obtained with acrylonitrile, which produced an 87 percent increase in compressive strength in concrete test specimens (4).

The large amount of either radiation or thermal energies required to perform the polymerization in the premix polymer concrete are so great that this method has not become economically practical to date (5). Research is now being directed toward development of a monomer-chemical system which, when premixed with the fresh concrete, will activate polymerization by the heat of hydration innate in the development of hardened concrete. The hydration of cement involves an exothermic chemical reaction which supplies about 25 calories per gram of cement (5).

## IMPREGNATION WITH THE MONOMER

The impregnation of hardened concrete with subsequent conversion has proven to be most successful. The compressive strength of the concrete is found to increase geometrically with the percentage of monomer loading.

The voids in concrete are normally filled with air and water, so that only a 1.9 percent weight increase in normal concrete can be achieved with direct monomer impregnation. If the voids are emptied of water by heating, the loading weight may be increased to 4.6 percent. By placing the concrete in a partial vacuum while heating, the air is also removed from the voids with a loading weight increase of about 6.5 percent (4). This is approximately 13 percent of the concrete volume and represents the total voids of a normal air-entrained concrete (7).

## MONOMERS AND POLYMERIZATION

Many of the available monomers are not acceptable in the production of polymer concrete. The monomer must have a low viscosity so that it can easily penetrate the voids in the concrete. It should have a boiling point above 158 F (70 C), in order for it to be handled without special equipment, and have strengths in its polymer form that are advantageous to the concrete. Some polymers are sufficiently low in tensile strength or have such a low stress-strain modulus as to be of little value in producing significant improvements in the physical properties of concrete.

Probably the most important consideration in the choice of a successful monomer are the initial cost and the amount of energy required to convert the monomer to a polymer.

Styrene and methyl methacrylate have been found to have desirable properties as monomers. Both cost approximately the same, but methyl methacrylate requires only one-tenth as much radiation energy to be converted to a polymer (4). This obviously permits a significant cost advantage. Methyl methacrylate has been used in most of the initial polymer concrete research and has provided the best benefit/cost ratio (4). Other monomers which have been tried or considered are: ethylene, ethylene-$SO_2$, vinyl acetate, methyl alcohol, vinyl chloride, isobornyl methacrylate, trimethylolpropane trimethacrylate, diallyl phthalate, Plaskon-941, Hetron-197, and Epocryl V-16.

The use of both radiation and thermal energy has been shown to be successful in causing the polymers to form. Polymer concrete formed with thermal energy was 7 to 15 percent lower in compressive strength than polymer concrete formed with radiation energy (8).

The use of thermal energy in the formation of polymer concrete induces a temperature gradient with resulting internal stresses. It is speculated that thermal stresses are the cause of some microcracks and internal bond ruptures (9). These could prevent the polymer concrete formed by thermal energy from achieving the strength of that formed by gamma radiation.

A cobalt-60 gamma-ray source is the most commonly used means of providing the radiation energy for the polymerizing process. Gamma radiation involves a direct energy transfer between the gamma-ray and the monomer (10), with little or no heating taking place.

## RESULTS AND POTENTIAL USES

Polymer concrete containing about 7 percent by weight of methyl methacrylate has shown excellent physical properties including: (a) tensile strength increased by 292 percent, (b) compressive strength increased by 285 percent, (c) freeze-thaw durability improved over 300 percent, (d) water permeability decreased to a negligible value, and (e) effect of sulfate attack and acid attack reduced to negligible values (4).

Obviously such concrete has many possibilities; however, current uses are confined to the precast concrete industry. Potential health hazards from the radiation source are easier to control by shielding at a central location, which suggests a casting plant situation.

A ready application for polymer concrete is in the manufacture of pipe. Pipe must be durable, withstand tensile loads and sulfate and acid attacks, and have low permeability. Since polymer concrete improves each of these properties over plain concrete and cost estimates have shown that it can be manufactured at approximately the same price as clay pipe, a market for polymer concrete pipe is being created (5).

Overall improvements in concrete properties lead to specialized applications in desalinization plants. Other uses are for underwater structures and in concrete exposed to sea water. Concrete located in the tidal zones are subject to severe chemical attack and weathering, wave action, and increased pressures.

Any structural concrete member produced in a central casting plant could, as needed, be made of polymer concrete, including prestressed elements, concrete piles, pressure vessels and precast housing units.

The potential uses of polymer concrete in the highway industry are numerous. Some of the most pressing problems which face civil engineers are concerned with concrete bridge deck deterioration. Surface treatment or initial construction changes which eventually produces polymer concrete could be of great value in prolonging the useful life of such structures. Hydraulic structures used in connection with highways could be benefited by the use of polymer concrete as well as pavements in areas where high concentrations of de-icing chemicals are used; extended use of prestressed elements could be permitted with the reduced permeability possible.

The incorporation of dyes (8) with the plastics used for polymerization opens another esthetic aspect of concern to civil engineers and architects, as does the potential size decrease for greater span/depth ratios.

Industrial floors subject to chemical attack and/or rapid wear would be benefited by the increased resistance and prolonged life of polymer concrete, and simultaneously facilitate the epoxy-type repair which is now most commonly performed on such areas.

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