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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20330684
Canadian Building Digest, 1985-10

Canadian Building Digest
Division of Building Research, National Research Council Canada

CBD-241

Polymer Modified Concrete

Please note

Originally published October 1985.

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Abstract

Polymer modified concrete may be divided into two classes: polymer impregnated concrete and polymer cement concrete. The first is produced by impregnation of precast hardened Portland cement concrete with a monomer that is subsequently converted to solid polymer. To produce the second, part of the cement binder of the concrete mix is replaced by polymer (often in latex form). Both have higher strength, lower water permeability, better resistance to chemicals, and greater freeze-thaw stability than conventional concrete.

Introduction

Although its physical properties and relatively low cost make it the most widely used construction material, conventional Portland cement concrete has a number of limitations, such as low flexural strength, low failure strain, susceptibility to frost damage and low resistance to chemicals. These drawbacks are well recognized by the engineer and can usually be allowed for in most applications. In certain situations, these problems can be solved by using materials which contain an organic polymer or resin (commercial polymer) instead of or in conjunction with Portland cement. These relatively new materials offer the advantages of higher strength, improved durability, good resistance to corrosion, reduced water permeability and greater resistance to damage from freeze-thaw cycles.

There are three principal classes of composite materials containing polymers: polymer impregnated concrete; polymer cement concrete and polymer concrete. The distinction between these three classes is important to the design engineer in the selection of the appropriate material for a given application. In this Digest, the nature and general properties of polymer impregnated concrete and polymer cement concrete materials will be briefly discussed. A subsequent Digest (**CBD 242**) will deal with polymer concrete, a composite containing polymer as a binder instead of the conventional Portland cement.

The typical properties of these polymer-containing composites are compared with those of conventional Portland cement concrete in Table I. Their general characteristics and applications are summarized in Table II.

Table I. Typical Properties* of Polymer-Containing Concrete Composites And Portland Cement Concrete[1,2]

Material	Tensile Strength, MPa	Modulus of Elasticity, GPa	Compressive Strength, MPa	Shear Bond Strength, KPa	Water Sorption, %	Freeze-thaw Resistance, No. of Cycles/ % Wt. Loss	Acid Resistance**
Polymer impregnated concrete	10.5	42	140	-	0.6	3,500/2	10
Polymer impregnated concrete***	14.7	49	273	-	≤0.6	-	≥10
Polymer cement concrete	5.6	14	38	≥4,550	-	-	4
Portland cement concrete	2.5	24.5	35	875	5.5	700/25	-

*The values given represent average values; the properties of commercial products may vary over a wide range, depending on formulation and production process.

**Improvement factor in relation to Portland cement concrete.

***Concrete autoclaved before impregnation.

Table II. General Characteristics And Applications of Polymer-Modified Concretes

Material	General Characteristics*	Principal Applications	Remarks
Polymer impregnated concrete	Consists generally of a precast concrete, which has been dried(and	Principal applications include use in structural steel	The disadvantage is the relatively

	evacuated) then impregnated with a low viscosity monomer(or mixture of monomers) that polymerizes in situ to form a network within the pores. Impregnation results in markedly improved strength and durability(e.g., resistance to freeze-thaw damage and corrosion) in comparison with conventional concrete.	floors, food processing buildings, sewer pipes, storage tanks for seawater, desalination plants and distilled water plants, wall panels, tunnel liners and swimming pools.	high cost, as the polymer is more expensive than cement and the production process is more complicated.
Polymer cement concrete**	Products made with thermosetting(cross-linked) polymers and polymer latex have greater mechanical strength, markedly better resistance to penetration by water and salt, and greater resistance to freeze-thaw damage than Portland cement concrete; excellent bonding to steel reinforcing and to old concrete.	Major applications are in floors, bridge decks, road surfacing and compounds for repair of concrete structures,(e.g. parking garage decks). Because of good adhesive properties, latex modified mortar is used for laying bricks, in prefabricated panels and in stone and ceramic tiles.	The mixing and handling are similar to Portland cement concrete. However, in the production process, air entrainment occurs without the use of an admixture, and prolonged moist curing is not required.

*Both polymer impregnated concrete and polymer cement concrete have considerably better resistance to chemicals than unmodified Portland cement. Test results have indicated that the polymer modified concrete has much greater resistance to aggressive fluids such as solutions of sodium sulfate or hydrochloric acid.[3-5] Concrete modified with poly(methyl methacrylate) is more resistant to solutions of hydrochloric acid than concrete modified with styrene.[3]

**Most commercial formulations in the USA and Canada use polymer latexes(for example acrylics and styrene-butadiene polymer); epoxy polymer cement concrete is used in applications similar to those of latex polymer cement concrete, but when greater strength is required.

Polymer Impregnated Concrete

Polymer impregnated concrete is made by impregnation of precast hardened Portland cement concrete with low viscosity monomers (in either liquid or gaseous form) that are converted to solid polymer under the influence of physical agents (ultraviolet radiation or heat) or chemical agents (catalysts). It is produced by drying conventional concrete; displacing the air from the open pores (by vacuum or monomer displacement and pressure); saturating the open pore structure by diffusion of low viscosity monomers or a prepolymer-monomer mixture (viscosity 10 cps; 1 x 10-2 Pa•s); and in-situ polymerization of the monomer or prepolymer-monomer mixture, using the most economical and convenient method (radiation, heat or chemical initiation). The important feature of this material is that a large proportion of the void volume is filled with polymer, which forms a continuous reinforcing network. The concrete structure may be impregnated to varying depths or in the surface layer only, depending on whether increased strength and/or durability is sought. The main disadvantages of polymer impregnated concrete products are their relatively high cost, as the monomers used in impregnation are expensive and the fabrication process is more complicated than for unmodified concrete.

Impregnation of concrete results in a remarkable improvement in tensile, compressive and impact strength, enhanced durability and reduced permeability to water and aqueous salt solutions such as sulfates and chlorides. The compressive strength can be increased from 35 MPa to 140 MPa, the water sorption can be reduced significantly. and the freeze-thaw resistance is considerably enhanced. The greatest strength can be achieved by impregnation of auto-claved concrete. This material can have a compressive-strength-to-density ratio nearly three times that of steel. Although its modulus of elasticity is only moderately greater than that of non-autoclaved polymer impregnated concrete, the maximum strain at break is significantly higher.

The monomers most widely used in the impregnation of concrete are the vinyl type, such as methyl methacrylate (MMA), styrene, acrylonitrile, t-butyl styrene and vinyl acetate. Acrylic monomer systems such as methyl methacrylate or its mixtures with acrylonitrile are the preferred impregnating materials, because they have low viscosity, good wetting properties, high reactivity, relatively low cost and result in products with superior properties. By using appropriate bifunctional or polyfunctional monomers (cross-linking agents) in conjunction with MMA, a cross-linked network is formed within the pores, resulting in products with greatly increased mechanical strength and higher thermal and chemical resistance. Improvement of these properties will depend on the degree of cross-linking. A cross-linking agent commonly used with vinyl monomers such as MMA and styrene is trimethylolpropane trimethacrylate.

Thermosetting monomers and prepolymers are also used to produce polymer impregnated concrete with greatly increased thermal stability (i.e. resistance to deterioration by heat). These include epoxy prepolymers and unsaturated polyester-styrene. These monomers and prepolymers are relatively viscous and, therefore, their use results in reduced impregnation. Their viscosity can be reduced by mixing them with low-viscosity monomers such as MMA.

Applications of concrete impregnated in depth in building and construction include structural floors, high performance structures. food processing buildings. sewer pipes. storage tanks for seawater, desalination plants and distilled water plants. marine structures, wall panels. tunnel liners, prefabricated tunnel sections and swimming pools (see Table II). Partially impregnated concrete is used for the protection of bridges and concrete structures against deterioration and repair of deteriorated building structures, such as ceiling slabs. underground garage decks and bridge decks.

Polymer Cement Concrete

Polymer cement concrete is a modified concrete in which part (10 to 15% by weight) of the cement binder is replaced by a synthetic organic polymer. It is produced by incorporating a monomer, prepolymer-monomer mixture, or a dispersed polymer (latex) into a cement-concrete mix. To effect the polymerization of the monomer or prepolymer-monomer, a catalyst is added to the mixture. The process technology used is very similar to that of conventional concrete. Therefore, polymer cement concrete can be cast-in-place in field applications, whereas polymer impregnated concrete has to be used as a precast structure.

The properties of polymer cement concrete produced by modifying concrete with various polymers range from poor to quite favorable. Poor properties of certain products have been attributed to the incompatibility of most organic polymers and monomers with some of the concrete mix ingredients. Better properties are produced by using prepolymers, such as unsaturated polyester cross-linked with styrene or epoxies. To achieve a substantial improvement over unmodified concrete, fairly large proportions of these polymers are required. The improvement does not always justify the additional cost.

Modification of concrete with a polymer latex (colloidal dispersion of polymer particles in water) results in greatly improved properties, at a reasonable cost. Therefore, a great variety of latexes is now available for use in polymer cement concrete products and mortars. The most common latexes are based on poly (methyl methacrylate) also called acrylic latex, poly (vinyl acetate), vinyl chloride copolymers, poly (vinylidene chloride), (styrene-butadiene) copolymer, nitrile rubber and natural rubber. Each polymer produces characteristic physical properties. The acrylic latex provides a very good water-resistant bond between the modifying polymer and the concrete components, whereas use of latexes of styrene-based polymers results in a high compressive strength.

Curing of latex polymer cement concrete is different from that of conventional concrete. because the polymer forms a film on the surface of the product. retaining some of the internal moisture needed for continuous cement hydration. Because of the film-forming feature, moist curing of the latex product is generally shorter than for conventional concrete.

Generally, polymer cement concrete made with polymer latex exhibits excellent bonding to steel reinforcement and to old concrete. good ductility. resistance to penetration of water and aqueous salt solutions, and resistance to freeze-thaw damage. Its flexural strength and toughness are usually higher than those of unmodified concrete. The modulus of elasticity may or may not be higher than that of unmodified concrete, depending on the polymer latex used. For example, the more rubbery the polymer. the lower the modulus. Generally, as the polymer forms a low modulus phase with the polymer cement concrete, the creep is higher than that of plain concrete and decreases with the type of polymer latex used in the following order: polyacrylate; styrene-butadiene copolymer; polyvinylidene chloride; unmodified cement.

The drying shrinkage of polymer cement concrete is generally lower than that of conventional concrete; the amount of shrinkage depends on the water-to-cement ratio, cement content, polymer content and curing conditions. It is more susceptible to higher temperatures than ordinary cement concrete. For example, creep increases with temperature to a greater extent than in ordinary cement concrete, whereas flexural strength, flexural modulus and modulus of elasticity decrease. These effects are greater in materials made with elastomeric latex (e.g., styrene-butadiene rubber) than in those made with thermoplastic polymers (e.g., acrylic).

Typically, at about 45°C, polymer cement concrete made with a thermoplastic latex retains only approximately 50 percent of its flexural strength and modulus of elasticity.

The main application of latex-containing polymer cement concrete is in floor surfacing, as it is non-dusting and relatively cheap. Because of lower shrinkage, good resistance to permeation by various liquids such as water and salt solutions, and good bonding properties to old concrete, it is particularly suitable for thin (25 mm) floor toppings, concrete bridge deck overlays, anti-corrosive overlays, concrete repairs and patching (see Table II).

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