

Strength degradation of polymer concrete in acidic environments

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Abstract

This paper presents an assessment of the chemical resistance of eight different compositions of polymeric mortars using four different concentrations of filler, fly ash, and two types of unsaturated polyester resins, namely isophthalic polyester and orthophthalic polyester. The samples were exposed to seven different acid environments that represent those that often account for corrosive processes in industrial environments. None of the compositions in the study showed evidence of physical surface changes nor weight loss. There was a decrease in the flexural strength of the samples exposed to corrosive agents and this effect was more pronounced in the compositions with lower filler concentrations. However, even in those samples, the remaining flexural strength values remained far higher than those found in mortars prepared with Portland cement, an inorganic binder. Statistical analysis showed that the type of resin, the concentration of filler and the type of corrosive solution used have a significant effect on the chemical resistance of the polymeric mortars investigated in this study. SEM analyses also showed that the chemical attack occurred in the polymer matrix–aggregate interface.

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1. Introduction

In the last few decades, polymers have been used in the production of concrete and mortar with improved mechanical strength and durability. The resulting compound is known as polymer concrete. The binder in polymer concrete is a resin that polymerizes with the aid of additives, namely an initiator and a catalyst [1,2]. Polymer concrete (PC) displays high compressive and flexural strength values, as well as improved chemical resistance to acid environments, particularly when compared with Portland cement concrete [3].

The hydration products of Portland cement concrete are alkaline and therefore react with acid environments. Over time, if exposed to acid environments, this type of concrete

will show signs of wear [4]. However, in the case of PC, the polyester, epoxy, vinyl, phenol and methylmetacrylate resins that are often used as binders show good chemical resistance to acid environments and the concrete prepared with these polymers tends to replicate the inherent characteristics of the binders used [3].

Gorninski et al. [5] believe polymer concrete is an example of a relatively new high performance material. Its excellent mechanical strength and durability reduce the need for maintenance and frequent repairs required by conventional concrete. Other advantages observed in the use of PC include its fast curing time, which greatly facilitates the production of precast members because the cast parts can be removed from their molds in a matter of hours. When PC is used in coatings or repairs, the structure involved can be back into service overnight [6,7]. These characteristics of PC are a result of the substitution of a polymeric material for the cement binder [8].

For Rebeiz and Fowler [9], PC is the material of choice for coatings because of its strong bonding with Portland

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cement concrete, its resistance to abrasion and weathering, its impermeability and the low weight resulting from the small layer thicknesses used. PC also shows good sound and thermal insulation properties because of its low thermal conductivity and good dampening characteristics. In hydraulic structures such as dams, dikes, reservoirs and piers, PC creates a highly abrasion-resistant surface [10].

Fowler [1] observed that in the United States, the most common applications of PC are found in highway surfaces and bridge decks as well as in the petrochemical industry. In Canada and Japan, PC is often used in underground constructions and road surfaces, mainly because of severe weather conditions. In Europe, however, a large share of the applications is represented by precast materials for the civil construction sector, in the metal-mechanical industry as a replacement for cast metals and in the construction of reservoirs and coating materials in the chemical and food industry.

Judging from the improved properties and flexibility of these materials, one would expect to find a vast field of applications for PC. However, the cost of the resins, which is far higher than that of cement, results in a more expensive final product when compared with conventional concrete and this limits the scope of applications of PC compounds, particularly in developing countries, as discussed by Gorninski [3] and Czarnecki [11]. At the same time, it is important to remember that PC compounds compare favorably in terms of costs when durable materials with reduced maintenance is required [5]. In addition, in most cases, because of their higher strength lower amounts of PC compounds are needed when compared with the amounts of Portland cement concrete needed to obtain materials with the same strength levels [9].

To address the questions above, a previous study of PC compositions was carried out in order to define the compositions used here. That first study provided optimal cost/performance compositions with better packing of aggregate materials. The performance of the different compositions tested in that study was evaluated by means of a mechanical property (i.e., compressive strength) and a property related to durability (water absorption) [3]. Two different polymers were tested: isophthalic polyester, the most common PC polymer, and orthophthalic polyester, which has a much lower cost but has seen limited use in PC compositions used in aggressive environments. Strength and water absorption were assessed in samples with four different filler (fly ash) concentrations and two different binders, resulting in eight different compositions.

2. Experimental program

2.1. Materials

2.1.1. Resins

Unsaturated polyester resins were used as binders. Polyester is one of the most common polymers used in the

production of PC because of its high performance, which results in durable PC with low permeability and fast cure [7,2]. In addition, polyester has a lower cost than epoxy resins and is readily available commercially. This study investigated PC compositions with isophthalic or orthophthalic polyester dissolved in styrene.

Isophthalic and orthophthalic polyester are produced using different reactants. Polyesters are produced through polycondensation reactions of dicarboxylic acids with dihydroxy alcohols. Isophthalic polyester (isopolyester) is produced using isophthalic acid while orthophthalic polyester is the result of a reaction with phthalic acid [12,13].

It is difficult to obtain high molecular weight orthophthalic polyester and for this reason, the chemical and mechanical properties of this material are inferior to those of isophthalic polyester. Phthalic anhydride shows a strong tendency to regenerate from the ester medium of the phthalic acid (reversible reaction), which increases the amount of low molecular weight chains (more susceptible to chemical attack) [13,14].

As isophthalic acid does not form cyclic anhydrides in isophthalic resins, regeneration does not occur and high molecular weight polyester (with longer chains) can be obtained. The carboxyl groups of isophthalic polyester are more widely spaced (meta position) and for this reason do not greatly affect the growth of the molecular chain of the polymer. As a result, the synthesis of long chains is possible and the final product shows increased mechanical strength [3,14,15]. Table 1 lists the main properties of the binders used in this study.

2.1.2. Filler and aggregate

Fly ash was chosen as a filler material because of the wide availability of this material in the state of Rio Grande do Sul, where it is a by-product of the burning of coal used

Table 1
Properties of unsaturated isophthalic and orthophthalic polyester

Property	Unsaturated isophthalic polyester (33–411)	Unsaturated orthophthalic polyester (10–228)
Brookfield viscosity @ 25 °C, 60 rpm (cp) ^a	400–650	250–350
Acid index (mg KOH/g) ^a	9–15	30 max
Tensile modulus (MPa) ^a	3200 min	2400 min
Flexural modulus (MPa) ^a	3500 min	3800 min
Linear shrinkage (%) ^a	2.0	1.0 max
Specific gravity (g/cm ³) – ASTM D 1475 ^b	1.0968	1.0955
Axial compressive strength (MPa) – ABNT 5738 ^b	117.31	91.44
Flexural strength (MPa) – ABNT 12142 ^b	29.45	17.23

^a Manufacturer data (Reichhold do Brasil).

^b Determined in this study.

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