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Effects of Gamma Irradiation on Polymer-Modified Concrete (PMC): A Review

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Polymer modified concretes have increased in recent years due to their high strength and durability. Polymer modification applied to cement mortars is widely used in the literature. This paper briefly reviews the changes in the material structure caused by gamma irradiation on polymer modified concretes. Many studies on the effect of gamma radiation on cementitious materials have focused mainly on physico-chemical evolution due to the effects of radiolysis. The effects of polymer crosslinking and deterioration in the structure of the polymer modified concrete by gamma irradiation result in improved interphase bonding, increase not only strength and durability but also thermal, abrasion and waterproofing properties. In this context, some important details of recent studies on the effects of gamma rays applied to polymer modified concretes have been interpreted.

Introduction

Since the 1950s, when synthetic polymers began to be incorporated into Portland cement mortars and concrete, there has been widespread interest in the use of synthetic polymer latex instead of rubber latexes in construction industries. Polymer latexes are suspended and water-insoluble polymer particles [1]. It is made of a core made of water-insoluble polymer and a stabilization system used to prevent agglomeration in the colloidal system [2]. Currently, latexes of a single or polymer options, such as polyvinyl acetate, vinyl acetate-ethylene, styrene-butadiene copolymers, styrene-acrylic, and acrylic and styrene-butadiene rubber emulsions are generally used in the manufacture of cement composites [3-8]. So far, many effective polymer modification systems have been developed for cement mortar and concrete and have been used in various applications in the construction industry since the concept of polymer modification for cement mortar and concrete was introduced more than 80 years ago. Recently, the application of concrete-polymer composites, in particular polymer modified mortar and concrete, is rapidly expanding due to its good properties compared to conventional cement mortar and concrete [9-11]. The term acrylic in acrylic polymers, which has long been used to develop Portland cement composites, represents a broad family of materials with a similar chemical structure but with a wide range of properties [12].

It is well known that by exposure of polymers to radiation, the structures prior to exposure are separated and degraded by the release of atoms, molecules and molecular particles. This event generates a series of transformed species, ions, free radicals and induces scission and crosslinking, or both. Gamma radiation causes both crosslinking and degradation during application, but one of these effects may be predominant in some materials. Crosslinking is the most important effect of polymer irradiation, since it usually leads to the formation of a network structure with an increase in the number of polymeric chains under the irradiation dose. Thus, as a result of improved inter-phase bonding, the mechanical strength, thermal and chemical environmental properties, workability, abrasion, bond strength, adhesion with substrates or waterproofing properties of mortars and concrete can be improved.

Microstructure of Polymers

Polymer concrete composites are generally classified as follows: Polymer impregnated concrete (PIC) which is polymerized in situ after impregnation with monomer, polymer concrete (PC) formed by polymerizing the monomer in the mixture and polymer modified concrete (PMC) or polymer Portland cement concrete (PPCC) where polymer modified monomer and aggregate used as binder. The polymer particles in Latex are dispersed homogeneously when

the polymer is mixed with fresh concrete. When hydration starts, ethenite and CH crystals are formed in the regions adjacent to the aggregates and a calcium silicate layer forms on the aggregate. With the consumption of water and the increase in hydration products as a result of hydration, polymer particles in the gel products gradually accumulate on capillary pores, unhydrated cement particles to form a layer on the gel product surfaces. The deposited polymer particles eventually fill almost all the capillary pores and cover the interior surfaces that are not fully filled. The amount of water, which is further reduced by hydration or drying, polymer particles located in the gel particles and cavities combine to form continuous films. Thus, a co-matrix is formed which binds the hydrates with aggregates and is interconnected to the cement paste [13].

Application

Polymer modified concrete is suitable for use in different structural and non-structural precast products such as tile adhesives, facade coatings, slabs, decorative coatings and as repair material in road buildings [14]. Resurfacing, flooring, and patching are among the current applications as the others like overlays on roadways and bridges, both as new construction and as repairs of existing deteriorated structures.

Polymer modified concrete has also recently been used with fiber reinforcement to reduce crack formation where high tensile strength, bond strength and impermeability is required [15-17]. In the future, it is considered to be used in roller-compacted concrete (RCC) for roadways and parking lots as well as marine and offshore structures.

Examples from Literature

MR Ismail et al [18] presented a study to investigate the effects of different doses of gamma rays on physico-chemical properties of prepared blended cement mortars. In this context, nano-calcined clay (NCC) replaced with Portland cement by different ratios and polyvinyl alcohol (PVA) were added to the resulting cement blend with percentages between 2 and 8. NCC used for the study obtained by heating at 750 °C for 2 hours with particle size of 60.6 nm. Results of this study showed that irradiation of blended cement mortars with the addition of PVA increased the compressive strength and bulk density up to 30 kGy of γ -irradiation absorbed dose value. However, between 30 & 50 kGy, a significant decrease has been observed for both properties. Total porosity and water absorption percentages improved due to increased PVA and irradiation dose. The reason for this was the deposition of solid materials in the pore system of composite. As a final conclusion, XRD, SEM and TGA applications have confirmed that chemical reactions between composite components occurred as a result of gamma irradiation [18]. MM Khatib [19] stated the effects of replacing the standard sand (SS) used for cement mortar production with white sand for white sand (WS) cement mortar production. In addition, alterations in physico-mechanical properties were also discussed by adding 10% styrene-acrylic ester (SAE) to two different types of mixed cement mortar in certain proportions and applying gamma rays at

different doses. 10% SAE was added to only the first two samples with partial replacement ratio of 10PC:2SS:1WS, 10PC:1SS:2WS and 10PC:0SS:3WS. The mixtures were molded into 2.5 x 2.5 x 2.5 cm cubes and then kept in a humidity cabinet at 25 °C for 24 hours. It was then irradiated at doses ranging from 10 kGy to 50 kGy. Replacement of standard sand with white sand resulted in a decrease in compressive strength. In addition, in the polymer modified mortars, the compressive strengths increased due to the decreased porosity as a result of increasing irradiation doses. Another conclusion was 10PC:1SS:2WS group samples were found to be more thermally stable. On the other hand, scanning electron microscopy (SEM) images showed the presence of SAE provided an improvement to polymer modified samples cured under gamma rays [19].

SH El-Hamouly et al [20] worked on the effects of irradiation dose and addition of styrene-acrylic ester (SAE) to cement mortars composites contain Nano calcined clay (NCC). In the preparation of the samples, the NCC was replaced with cement at 5 and 10%. SAE was added to the blended cement mortars at different rates (2, 4, 6, 8, 10 and 15%) and irradiated with gamma rays at various doses (from 10 to 50 kGy). NCC was prepared by heating clay at 750 °C for 2 hours with a particle size of 65.3 nm. SAE latex supplied for the work had a density of 1.04 g/cm³ and 57% solid content percent. As a result, it was found that the SAE polymer tends to form film around the cement particles during hydration of cement in the presence of NCC, which is reported to be dependent on the polymer/cement ratio and the amount of gamma irradiation dose. Compressive strength values of NCC-SAE cement mortar were increased until a certain polymer/cement ratio and gamma irradiation dose. After some amount of irradiation dose and p/c ratio, compressive strength was found to gradually decrease as polymer seals the pores and microvoids. TGA, XRF and SEM observations were stated interactions between SAE polymer molecules, hydrated cement and NCC particles. Also, SAE polymer modifies the microstructure of the hydration products of blended cement and form a dense matrix. In addition, it has been reported that the SAE polymer affects the microstructure of the hydration products of the cement blend to form a denser matrix [20]. M Martinez-Lopez et al [21] reported the evaluation of mechanical, morphological and thermal properties of polyester resin and silica sand-based composites which are formed by partial replacement of Tetra Pak particles with silica sand and applied to gamma rays. Tetra Pak has a total of six layers, four of which are polyethylene, one cellulose and one aluminum. Samples prepared for experiments were a composite material prepared by milling a Tetra Pak package to 2 - 4 mm sized rectangular particles and replacing those by silica sand in percentages of 1, 2, 4 and 6 and adding them to the cement mix. Samples have been exposed to gamma rays at doses between 100 and 500 kGy to provide a better interfacial surface coupling between the matrix and Tetra Pak particles. It is concluded that highest compressive and flexural strength values were achieved when 1 wt.% of Tetra Pak particle is added. At high doses of irradiation, the composites showed a considerable increase deformation due to pressure and bending;

maximum deformation was observed at 400 kGy (26% higher than control mortar) and 500 kGy at bending (36% higher than control mortar). It was suggested that gamma rays created cross-linking and degrading effects on polyethylene, cellulose and polyester matrix [21].

AAM Yassene et al [22] observed the effect of styrene-butadiene-rubber (SDR) polymer/cement ratio under the conditions of gamma irradiation dose on physico-mechanic properties of cement mortar. Samples were prepared in different SBR/cement mass ratios (2.5, 5, 10, 15 and 20), then wet and dry curing method was applied. Gamma irradiation were applied to the resulting samples at 10, 30 and 50 kGy doses. Ordinary Portland cement (OPC) was used as cement type and standard sand was used as aggregate. Polymer modified mortar samples were prepared with cement sand ratio by mass at [1.0:3.0] and cement water ratio by mass at [1.0: 0.45]. The results showed that as the amount of latex polymer in composites increased, ordinary Portland cements showed a noticeable decrease in compressive strength values. In addition, it was determined that dry cured samples had higher compressive strength than wet cured samples. The compressive strength values of the samples increased as the irradiation dose increased. Only a slight decrease was observed after about 40 kGy in wet cured samples of 7 days. It was found that the total porosity and bulk density of the composites decreased with increasing polymer/cement ratio, while the total porosity decreased, and bulk density increased with increasing absorbed dose. The results of XRD, TGA and SEM studies were consistent with the physico-chemical and mechanical results obtained from experiments [22].

Acknowledgment

None.

Conflict of Interest

No conflict of interest.

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