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Investigations of addition of low fractions of nanoclay/latex nanocomposite on mechanical and morphological properties of cementitious materials

Mehdi Hatami [a,*], Akbar Dehghan [b], Nader Djafarzadeh [c]

[a] *Polymer Research Laboratory, Department of Polymer Science and Engineering, University of Bonab, P.O. Box 5551761167, Bonab, Iran*
[b] *Department of Chemical Engineering, Mahshahr Branch, Islamic Azad University, Mahshahr, Iran*
[c] *Department of Chemistry, Miyaneh Branch, Islamic Azad University, Miyaneh, Iran*

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Abstract In this study, we report the synthesis, characterization and performance of organic-inorganic hybrid (OIH) cementitious nanocomposites. OIH was synthesized by the insertion of polymer latex particles in the structure of clay nanoplates. Polymer latex particles were prepared by the polymerization of three different organic monomer comprising styrene monomer (St), 2-ethyl hexyl acrylate (EHA), and methacrylic acid (MAA). Poly(St/EHA/MAA) was prepared by a semi-continuous emulsion polymerization process. The prepared OIH was used to modify the cement paste properties. For the fabrication of latex structure various composition of methacrylic acid as a functional monomer was examined. The effect of the variety of the percentage of MAA on latex composition, and also the OIH to cement ratios were optimized. The optimum conditions were applied to the fabrication of nanoclay based blends. The effects of OIH onto the cement paste properties were evaluated by measuring of the compressive and flexural strength analyses. The obtained results showed that the best composition in cementitious matrix was related to the sample of OIH namely CP565, in which comprises of five percent nanoclay. Also FT-IR, XRD, and SEM analyses were performed to exactly identify the effects of OIH onto the cementitious matrix properties.

1. Introduction

Concrete is basically comprised of three main components including water, aggregate and Portland cement. Therefore, concrete is a composite material (Sasmal et al., 2017). When aggregates are mixed with Portland cement and water, the slurry is formed. In this process the water and other

* Corresponding author.
E-mail address: Hatami@bonabu.ac.ir (M. Hatami).
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ingredients react chemically with cement to form an inflexible matrix (Gdoutos et al., 2016). Often, additives are included in the mixture to improve the physical properties of the wet mix or the finished product. Most concretes are filled with reinforcing materials embedded to provide tensile strength, yielding reinforced concrete. Thus, for designing of the cement based composite, the interrelation between fillers and matrix in used process method must be investigated. Over the past decades, polymer-organo modified layered silicate (LS) nanocomposites have attracted great attention from academics to industrial aspects (Faghihi et al., 2017; Ke and Stroeve, 2005). The successful preparation of a fully delaminated construction of LSs and obtaining the good dispersion properties of them in used matrices points to improve in thermal, mechanical, flame resistance and gas barrier properties in combination with light weighting of the final products (Mico-Vicent et al., 2017). The LS showed high aspect ratio and had a width of one nanometer, which ideal candidate as reinforcement agent for different soft and hard matrices (Bertolino et al., 2016). LS showed a very good interaction with functional polymeric structures (Hakamy et al., 2014). Montmorillonite (MMT) is the most widely used LS due to its natural existence and some outstanding properties such as high surface area and also high aspect ratio (Chakrabarty et al., 2015; Kafi, et al., 2016). Modifications of LS as fillers by organic compounds are required for improve the compatibility between organic and inorganic segments. For modification of LSs the cation exchange capacity of them were used by different organic and inorganic moieties. In the most applications the modified LSs as known as organoclays were applied. Due to the large surface area of organoclays, the efficiency of these structures in the dispersed media matrices is very good (Cook et al., 2015; England et al., 2016; Simari et al., 2016). Nevertheless, there are some important drawbacks on cementitious composite materials or concretes such as fluidity, flexural strength, and corrosion properties (Schlumpf et al., 2013). Until now, different macromolecules have been fabricated and investigated in numerous application areas such as sensors, adhesives, and so on (Dastan et al., 2015; Hatami et al., 2015; Hatami, 2017; Karimi-Maleh et al., 2014; Mallakpour et al., 2011; Marandi et al., 2012). Modification of cement by using polymer additives have been attracted the industrial researchers' attention. Numerous kinds of polymer-modified mortars and concretes were introduced such as water-soluble polymer, latex polymer powder, liquid resin, and monomer-modified mortars and concretes (Han et al., 2015; Ohama, 1995). To yield a monolithic matrix phase with a network structure with superior properties, the cement based materials were well mixed with polymer phase. It is very important that both hydration of the cement and coalescence of macromolecule particles were well interpenetrated (Afridi et al., 2003). A co-matrix phase in the macromolecular modified mortar and concrete structure was illustrated by bound the aggregates by polymer/cement ingredients. In spite of the complexity of interactions between cement and polymer, some researchers have explained the mechanisms by which the polymer bonds to the cement ingredients (Li, 2011). The polymeric latexes are the most interested soft materials which have been used to improve the concrete properties. The effects of polymer latex particles on the mechanical properties of the mortar and concrete have been investigated by many researchers. Several parameters, such as polymer/cement ratio, type of cement, polymer functionality, and chemical structure of macromolecule, surfactant type, polymer-glass-transition temperature, and polymer particle size can considerably affect the mortar and concrete properties (Ohama, 1995; Walling and Provis (2016)). Although many scientists have been investigated the effect of polymeric materials onto the cement and concrete properties, less attention has been paid to the use of functionalized polymer latexes, nanoscale fillers and polymer filled with nanoscale particles as nanocomposite additives in this area. Mendoza Realesa et al. (2018) have reported the effects of dispersed multiwall carbon nanotubes (MWCNT)/surfactant on the Portland cement pastes properties. They mentioned that the dispersion of modified MWCNT cause to direct shift to higher yield stress values of cement whereas keeping the viscosity values for measured samples. They concluded that the interaction between MWCNT, surfactant, and cement directs the rheological properties of the cement. Niewiadomski et al. (2017) have reported the production and microstructural analysis of self-compacting concrete by addition of nanoscale fillers. They fabricated the concrete structure with different amounts of silica, titana and alumina nanoparticle as additives. They mentioned that the insertion of nanoparticles in structure of self-compacting concrete improves the microstructure of provided concrete. The study by Xu et al. (2018) displayed that the addition of low dosage of silica and titana nanoparticles in concrete composition could improve the environment resistance of concretes. Bai et al. (2018) reported the enhancement of electrical and mechanical properties of graphene/cement nanocomposite due to the enhancement in distribution of graphene nanosheets by addition of silica fume. Obtained results by this research group revealed that silica fume was capable to aid the distribution of graphene in cement and increase the interfacial strength between graphene and cementitious matrix. According to the reported results from prior studies (Bai et al., 2018; Mendoza Realesa et al., 2018; Niewiadomski et al., 2017; Xu et al., 2018) in the application of nanoscale fillers in cement matrix, it can be understood that the properties of cementitious materials are influenced by various factors, including the size, type, shape, dispersion method and the dosage of nanomaterials. Though previous investigations have proved that the nanostructure fillers have positive effects on physical and mechanical properties of cementitious materials, however, to the best of our knowledge, the application of the polymer filled nanostructures as nanocomposites on the performances of cementitious matrix is not yet accomplished. This research area still needs to be further investigate.

This paper presents the preparation of poly(styrene/2-ethylhexyl acrylate/methacrylic acid), poly(St/EHA/MAA)/LS blend nanocomposite and the dispersion of organic-inorganic hybrid (OIH) nanocomposite as a new admixture in cement composition for the first time. The technique of OIH preparation included both the semi-continuous emulsion polymerization and sonication method. The first step was the preparation of latex-based LS nanocomposite by using physical and chemical approach in order to achieve high degree of exfoliated dispersion, which was followed by the insertion of the prepared OIH into the cement paste. WXRD studies were carried out to visualized the type and degree of clay dispersion in the poly(St/EHA/MAA) matrix. Fourier transform infrared (FT-IR) analysis of polymer structure, OIH and its blend structure also have been carried out to investigate the polymer-clay and OIH- cement interactions. Also, the effects

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