Colloids and Surfaces A: Physicochem. Eng. Aspects 520 (2017) 154–165

Contents lists available at ScienceDirect

Colloids and Surfaces A: Physicochemical and Engineering Aspects

journal homepage: www.elsevier.com/locate/colsurfa

Research Paper

Effect of colloidal polymers with different surface properties on the rheological property of fresh cement pastes

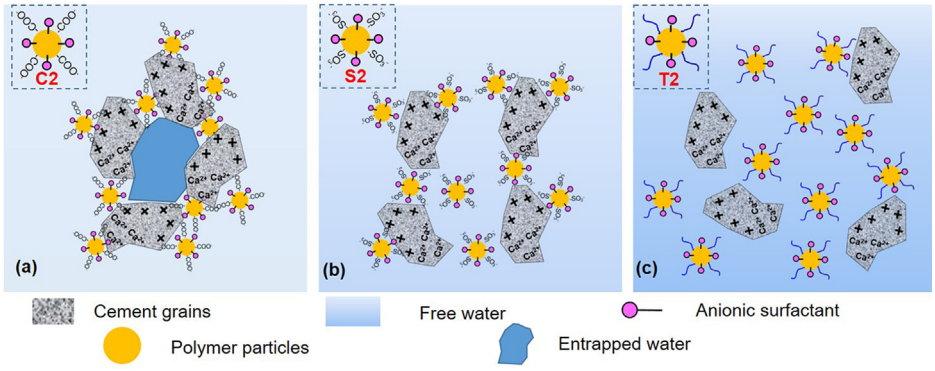
Zichen Lu[a], Xiangming Kong[a,*], Chaoyang Zhang[a], Feng Xing[b], Yanrong Zhang[a]

[a] Department of Civil Engineering, Tsinghua University, Beijing, 100084, China
[b] Department of Civil Engineering, Guangdong Provincial Key Laboratory of Durability for Marine Civil Engineering, Shenzhen University, Shenzhen, 518060, China

HIGHLIGHTS

- Effects of polymer on rheological properties of fcps are highly related to the adsorption behavior of polymer particles on surface of cement grains.
- Carboxyl groups on the surface of polymer particle cause the agglomeration of cement grains.
- Polymer particles with PEO hairy layer increase the fluidity of fcps.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 20 October 2016
Received in revised form 18 January 2017
Accepted 23 January 2017
Available online 24 January 2017

Keywords:
Polymer particle
Surface property
Rheological property
Fresh cement paste
Adsorption

ABSTRACT

Effect of colloidal polymers with different surface properties on the rheological properties of fresh cement pastes (fcps) was studied and the mechanism was discussed. It is found that the surface property of polymer particles is a key factor determining the impacts of polymer latexes on the rheological properties of fcps. The rheological properties of fcps with the addition of various polymer latexes are highly related to the adsorption behavior of the polymers. The abundant carboxyl groups located on the surface of polymer particles promote the adsorption of the polymer on cement grains and hence cause the agglomeration of cement grains, which leads to the decrease of fluidity, the increase of plastic viscosity and yield stress of fcps. Polymer particles with PEO hairy layer prefer to be flowing in aqueous phase and thus increase the fluidity and decrease the plastic viscosity of fcps. This paper scientifically discloses the importance of surface property of polymer particles on the rheological property of fcps and practically provides an effective technical approach to modify the rheological property of fcps by tuning the surface properties of colloidal particles when a polymer latex is used in the cementitious application.

1. Introduction

Polymer latexes have been widely used in cementitious materials for improvement of various properties, such as impermeability, durability, adhesive and mechanical strength, toughness [1–4]. Among the desired properties of cementitious materials, rheolog-

* Corresponding author.
E-mail address: kxm@mail.tsinghua.edu.cn (X. Kong).

http://dx.doi.org/10.1016/j.colsurfa.2017.01.067
0927-7757/

ical property is one of the most important properties that directly decides the practical workability of the cementitious materials in engineering, such as the pumpability, self-leveling and compacting, and the ability to penetrate into voids [5]. Polymer latex is commonly regarded as a dispersion system in which colloidal particles are dispersed in a medium, usually in water [6]. The size of the colloidal particles ranges from tens of nanometers to micrometers. When the polymer dispersion is added into cementitious materials, the colloidal polymer may exert great impacts on the rheological properties of the freshly mixed cementitious materials, because of the interaction between polymer particles and the cementitious materials. On the one hand, the high concentration of ions, particularly calcium ions in the interstitial solution of fresh cement paste (fcp) may cause the occurrence of coagulation of the colloidal particles due to the interaction between the colloidal particles and the ions [7]. One the other hand, the colloidal particles may interact with cement grains in fcp, e.g. being adsorbed onto the cement grains or crosslinking cement grains. As a consequence, both of the aforementioned processes may cause a great change of the rheological properties of fcps. Therefore, deep understanding of the rheological properties of the cementitious materials containing polymer latexes is of both scientific and practical importance, and has attracted great attention in recent years. Bessaies-Bey et al. [8] studied the effect of polyacrylamide (PAM) on the rheological properties of fresh cement pastes (fcps) and found that PAM micro-gel was formed through the complexation of calcium ions and then bridged several cement grains. Finally, the yield stress was significantly increased compared to the blank cement paste. Betioli et al. [9] studied the effect of ethylene vinyl acetate (EVA) co-polymer on the rheological properties of fcps and found that the addition of EVA reduced yield stress and viscosity of fcps at low shear rates during the first minutes of hydration due to the combined dispersing and ball-bearing effect. Besides, high shear rate led to desorption of EVA particles from the surface of cement grains and then resulted in the shear thickening of cement paste. Allan [5] studied the effect of carboxylated styrene butadiene dispersion (SBR) on the rheological properties of fcps. He found that the yield stress and the shear stress at any given shear rate were increased by the addition of the latex and this could be attributed to the increased inter-particle attraction.

The above mentioned literatures particularly focus on the effect of different types of polymer on the rheological properties of cementitious materials. In our previous study [10,11], it has been certainly verified that instead of the polymer composition of the latex, the surface properties of the colloidal particles, originating from either the surfactants or the functional monomers such as carboxyl group containing monomers, are the main decisive factor for the interaction between cement and polymers. It was disclosed that the adsorption of the colloidal particles is highly dependent on the surface charges of the colloidal particles. Thereafter, a question how the surface properties of colloidal polymers affect the rheological properties of cement pastes needs to be answered.

In order to disclose the impacts of the surface properties of colloidal particles on the rheological properties of cement pastes, three polystyrene dispersions with varied surface properties of the colloidal particles by copolymerization of styrene with different functional monomers, namely methacrylic acid (MAA) for providing carboxyl group, 2-acrylamido-2-methyipropane sulfonic acid (AMPS) for providing sulfonate group and isoprenyl oxy poly(ethylene glycol) macromonomer (TPEG) for forming polyethylene oxide (PEO) hairy layer on the surface of colloidal particles were prepared via emulsion polymerization. The influences of the three latexes on the rheological properties of cement pastes were evaluated by fluidity tests, plastic viscosity, yield stress measurements and micro-rheology measurement of fcps. The mechanism behind such effects was investigated by exploring the adsorption behaviors of the three colloidal polymers on the surface of cement grains using techniques of deletion measurement and confocal laser scanning microscope.

As far as the impacts of polymer latexes on the rheological properties of cementitious materials are concerned, to our best knowledge, no literature has been published dealing with the effect of surface properties of colloidal polymer on the rheological properties of cementitious materials. This paper intends to close this gap and is believed to benefit both the scientific understanding and practical applications of polymers latexes in construction application.

2. Experimental

2.1. Materials

Analytical grade chemicals, styrene (St), methacrylic acid (MAA), sodium persulfate (SPS), 2-acrylamido-2-methyipropane sulfonic acid (AMPS), sodium hydroxide were used as received (all >98% purity). Isoprenyl oxy poly(ethylene glycol) macromonomer (TPEG) with M_w of 2400 was provided by Liaoning Kelong Fine Chemical Co., Ltd. Emulsifier CO-458 (60 wt.% aqueous solution) and emulsifier OP-10 (40 wt.% aqueous solution) were provided by Haian petrochemical factory. Deionized (DI) water was used in all experiments in this study.

Commercial reference cement P·I 42.5 complying with the Chinese standard GB8076-2008 was used and its composition is given in Table 1.

2.2. Synthesis and characterization of the polystyrene latexes

The polystyrene latexes with varied surface properties were synthesized via semi-batch emulsion polymerization using styrene as the main monomer and MAA, AMPS and TPEG as the functional monomers (2 wt.% in the total monomer mass) to tune the surface properties of the obtained colloidal particles. The obtained polymer latexes using MAA, AMPS and TPEG as functional monomers are respectively symbolized as C2, S2 and T2. It is easily understood that the functional monomer MAA provides carboxyl groups and AMPS brings sulfonate groups on the surface of colloidal particles in the obtained latexes C2 and S2, while the copolymerization of TPEG macromonomer results in PEO hairy layer on colloidal particle surface of T2. The schematic drawing of the colloidal particles in the three synthesized latexes is presented in Fig. 1.

It is well known that a polymer latex is composed of polymer particle phase and aqueous phase that contains a tiny amounts of residual monomers, free emulsifiers and salts [6,10]. In order to avoid the impacts of these aqueous components on the aforementioned experimental results, purified polymer latexes by dialysis technique were used in all experiments of this study. The detailed

Table 1
Chemical and mineralogical compositions of cement. (wt.%).

Chemical composition								LOI	Mineralogical composition			
CaO	SiO_2	Fe_2O_3	Al_2O_3	SO_3	MgO	Na_2O_{eq}	f-CaO		C_3S	C_2S	C_3A	C_4AF
64.90	21.68	3.70	4.80	0.29	2.76	0.56	0.93	0.38	57.34	18.90	6.47	11.25