



Contribution of non-adsorbing polymers to cement dispersion



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ABSTRACT

It has been noticed recently that at low w/c ratios (≤ 0.30), non-adsorbed polycarboxylate (PCE) polymers can contribute as well to cement dispersion. This study aimed at defining more specifically the structural requirement for such non-adsorbing polymers. For this purpose, a cement paste (w/c = 0.30) containing a conventional MPEG PCE superplasticizer was admixed with additional quantities of a polyester polymer prepared via homopolymerization of MPEG methacrylate ester macromonomer, the macromonomer used in the homopolymerization, and the polyethylene glycol contained in the macromonomer. It was found that when admixed individually, all three polymers do not adsorb on cement and cannot fluidize the paste but enhance dispersion and fluidity significantly when combined with the PCE superplasticizer. A potential explanation is that the non-adsorbing polymers act as lubricants between cement, which are particularly densely packed at low w/c ratios. The pore fluid loaded with non-adsorbed polymer exhibits superior lubrication compared to pristine cement pore solution.

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1. Introduction

Colloids represent a class of nano- and micrometer sized particles which exhibit some unique properties [1]. Among them is their ability to scatter light when dispersed in a medium, which is commonly referred to as the *Tyndall effect* [2]. Typical colloidal materials are the different kinds of clays including bentonite, kaolinite, and attapulgite, as well as cement powder. When dispersed in water, colloids form suspensions exhibiting different viscosities depending on their particle size, density, pH-dependent surface charge, and the ionic strength of the aqueous phase. Cement dispersed in water produces an exceptionally high viscosity when compared with similar suspensions prepared from silica (SiO₂) or limestone (CaCO₃) powder of the same particle size. The reason behind is the heterogeneous surface charge of a cement particle stemming from the presence of different clinker phases (the aluminates C₃A and C₄AF exhibit a positive and the two silicate phases C₃S and C₂S a negative surface charge) [3]. Contrary to cement, SiO₂ or CaCO₃ possess homogeneous surface charges and thus do not much agglomerate in water via attraction of oppositely charged surface sites, as is the case for cement [4]. Therefore, to achieve a concrete or mortar of high fluidity and low viscosity, it is necessary to add a superplasticizing chemical admixture, which can disperse the large agglomerates into individual cement particles.

Generally, for the dispersion of particles in a medium, three principle mechanisms are being discussed in the literature: electrostatic, steric, and depletion stabilization [5,6].

- (1) Electrostatic stabilization can be achieved when two particles exhibit the same electrical charge. This concept was introduced by *Derjaguin, Landau, Verwey, and Overbeek*, who independently worked on the stability of lyophobic colloids (oil/water emulsions) [7,8]. According to their model, which is now known as DLVO theory, the electrostatic repulsion potential is expressed by the equation as follows:

$$V_{\text{repulsive}}(d) = \frac{a \cdot 32 \cdot \varepsilon \cdot \varepsilon_0}{\sigma} \cdot \left(\frac{R \cdot T}{F} \right)^2 \cdot \gamma^2 \cdot e^{-\kappa d} \quad (1)$$

where d is the interparticle distance, a is the particle radius, ε is the permittivity, ε_0 is the permittivity of vacuum, σ is the charge of ions, F is *Faraday's constant*, R is the universal gas constant, T is the temperature, and $\gamma = (e^{z/2} - 1) \times (e^{z/2} + 1)$.

The electrostatic repulsion between two particles strongly depends on the *Debye length* $1/\kappa$ and thus on the thickness of the diffuse ion cloud around a particle. Therefore, high ionic strength caused by high electrolyte concentrations as are present in cement pore solution reduce the repulsive force between particles [9].

It is commonly believed that polycondensate-based superplasticizers such as, e.g., β -naphthalensulfonate formaldehyde, melamine formaldehyde sulfite, or acetone formaldehyde sulfite predominantly achieve dispersion of cement via this mechanism,

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