Case Studies in Construction Materials 3 (2015) 9–18

Contents lists available at ScienceDirect

Case Studies in Construction Materials

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

Short communication

Influence of superplasticizer on the rheology of fresh cement asphalt paste

Jianwei Peng [a,b,*], Dehua Deng [a], Hai Huang [a,b], Qiang Yuan [a], Jianguo Peng [c]

[a] School of Civil Engineering, Central South University, Changsha 410075, China
[b] Anhui Engineering Material Technology Co., Ltd of CTCE Group, Hefei 230023, China
[c] Anhuiheda Environmental Detection Services Co., Ltd, Hefei 230023, China

ARTICLE INFO

Article history:
Received 1 December 2014
Received in revised form 23 May 2015
Accepted 24 May 2015
Available online 30 May 2015

Keywords:
Cement asphalt paste
Superplasticizer
Rheology
Zeta potential
Adsorption

ABSTRACT

Cement asphalt (CA) paste is an organic–inorganic composite material of cement and asphalt emulsion. Its complicated rheological behavior affects its site application in high speed railway. Superplasticizers (SPs) are usually used to improve the construction properties of fresh CA mortar. However, the principle of SPs acting on the rheology of CA paste is seldom studied. In this paper, the effects of polycarboxylate (PCA) and naphthalenesulfonate (PNS) on the rheological properties of CA pastes, asphalt emulsions (both anionic and cationic) and cement pastes were studied, respectively from the viewpoint of adsorption and zeta potential. Centrifugation method was used to determine the adsorption of asphalt onto cement particle, electroacoustic method was employed to study the zeta potential of cement particles of concentrated paste, and optical microscopy was used to observe the dispersion of particles. The results suggest that both PCA and PNS can decrease the yield stress and apparent viscosity of CA pastes. The effect of SPs on the rheology of CA paste can be explained by two reasons. First, PNS can adsorb on both asphalt and cement surface, change the zeta potential and then decrease their yield stress and viscosity, while PCA only adsorb on cement surface. Second, the competitive adsorption of SPs and asphalt prevents asphalt from adsorbing on cement surface and then more asphalt droplets are released into aqueous solution, thereby enhancing the particle dispersion.

1. Introduction

Slab track systems of types CRTS I and CRTS II have been developed in China, which have been widely used in high speed railway in China. Cement asphalt (CA) mortar is used in the slab track systems as a cushion layer, which fulfills important structural functions (Zhao et al., 2008; Zuo et al., 2005). It consists of cement, asphalt emulsion, aggregate, water and other admixtures. The asphalt emulsion is one of the key composite materials of CA mortar. It is a thermodynamically unstable system with asphalt droplets uniformly dispersed in an aqueous solution of water, emulsifier and some admixtures (Tharwat, 2013; Wang et al., 2012).

* Corresponding author at: School of Civil Engineering, Central South University, Changsha 410075, China. Tel.: +86 13487561607.
E-mail address: 515709546@qq.com (J. Peng).

http://dx.doi.org/10.1016/j.cscm.2015.05.002
2214-5095/

In the authors' previous work (Peng et al., 2014a,b), it is found that the yield stress and viscosity corresponding with practical engineering is very important for its construction quality. CA mortar is characterized by its high fluidity so that it can be placed without vibration, and easily grouted into the chamber between the concrete roadbed and track slab on site. In this respect, it should have a low yield stress, which can increase the spread-ability, however, also increase the probability of aggregate and bubble separation at the same time (Peng et al., 2014a; Feys et al., 2009; Cyr et al., 2000). The static segregation of aggregate and bubble is mainly governed by the yield stress, aggregate density and size. The dynamic segregation of aggregate is mainly governed by viscosity, aggregate density and size. Consequently, the yield stress and viscosity should be in an appropriate range-not too big or too low (Ouyang and Tan, 2015). Consequently, studying the rheological behavior of CA paste, especially the principle controlling its rheological behavior, is urgently needed.

CA mortar can be seen a particle suspension with aggregates dispersed in CA paste (Peng et al., 2014a,b; Zhang et al., 2012). Thus, the rheological behavior of CA mortar is depended on aggregates and particularly, the rheological behavior of CA paste. Only few publications were dealing with the rheological behavior of CA paste. Wang et al. (2008) had studied the rheological behavior of CA paste and the effect of thickener and silica fume, and asphalt to cement ratio (A/C). Zhang et al. (2012) had studied the influencing factors of type of asphalt emulsion, asphalt emulsion content, temperature, and shelf time on the yield stress of CA paste. Hu et al. (2009) had found that both anionic and cationic asphalt droplets exhibited favorable adsorption onto cement grain surface. Ouyang and Tan (2015), Ouyang et al. (2014) and Tan et al. (2014) had studied the rheological model, factors such as polycarboxylate superplasticizer influencing rheological parameters, demulsification process of asphalt emulsion of fresh CA paste. In the previous work, the research group had found that Herschel–Bulkley model is most suitable to character the rheological behavior of CA paste, and analyzed the effects of A/C and solid volume fraction (V_s) on the rheological behavior of CA paste (Peng et al., 2014a). Above all, the rheological behavior of CA paste is mainly determined by cement, asphalt emulsion and their relative proportion. Nevertheless, few chemical admixtures have been designed for CA mortar for the purpose of controlling its rheological behavior, and few studies have been dealing with it.

For fresh cement-based materials, SPs are often adopted to improve their rheology (Mikanovic and Jolicoeur, 2008; Papo and Piani, 2004). SPs are nowadays widely employed in cement technology, since they improve workability at a given water/cement ratio, or, on the other hand, they allow the same workability to be obtained as that of plain cement paste with a great reduction in water content, as well as final products with higher mechanical strengths to be manufactured (Papo and Piani, 2004). The increase in cement paste fluidity by the addition of SPs is connected with the dispersing action exerted by the adsorption of SPs on the cement surface, which modifies the zeta potential of particle or favors their dispersion on account of a phenomenon of steric impediment (Papo and Piani, 2004).

No specialized SP was developed for CA mortar, despite its widespread use in the area of high speed railway in China. More in-depth studies are needed on this field. In the previous work (Peng et al., 2014a), the authors had found that SPs can decrease the apparent viscosity and extent of shear-thinning of CA paste. Ouyang (Tan et al., 2014) had found that polycarboxylate superplasticizer (PCA) can reduce the initial yield stress and plastic viscosity, prevent CA paste from flocculation in order to reduce the yield stress growth rate, and PCA is not related with the growth rate of plastic viscosity. CA mortar used in ballastless track has very high asphalt emulsion content, ranging from 50% to 140% of cement by weight, which is much higher than that of ordinary polymer modified cement materials. Thus, CA mortar could be either cement-based or asphalt-based, whose rheological behavior is very complicated. The effect of SPs on the rheology of asphalt emulsion and cement paste should be clarified respectively. And then the effect of SPs on the rheology and particle dispersion of CA paste is analyzed. In CA paste, asphalt droplets can adsorb on cement surface and increase the cement dispersion (Peng et al., 2014a; Hu et al., 2009). When SPs and asphalt emulsion are added into cement paste at the same time, there may be a competitive adsorption of asphalt and SPs on cement surface, which has an influence on the particle dispersion of CA paste (Shiyun et al., 2010; Beaudoin and Ramachandran, 1989).

A multi-method approach is required to understand different aspects of SP behavior in fresh CA paste. Yield stress and apparent viscosity are the two main rheological parameters which are used to quantify the effect of SP addition to the cement based paste. Considered that CA paste is a composite of asphalt emulsion and cement, the effect of SPs on the rheology of asphalt emulsion and cement paste is first studied respectively in this paper. The zeta potential measurement is adopted to study the adsorption of SP molecules on asphalt and cement surface. An asphalt adsorption measurement is used to analyze the effect of SPs on the particle dispersion of asphalt and cement in CA paste. Optical microscopy observation was made on the paste to study the particle dispersion.

2. Experimental

2.1. Materials and formulation procedure

2.1.1. Cement and asphalt emulsion

CA pastes were prepared with a Portland cement, which physical properties and chemical composition are listed in Tables 1 and 2, respectively, and a cationic and anionic emulsified emulsion which physical properties are listed in Table 3. The particle size distribution of cement and asphalt are shown in Fig. 1.