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The role and interaction of superplasticizer and emulsifier in fresh cement asphalt emulsion paste through rheology study

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HIGHLIGHTS

- The effect of superplasticizer on asphalt emulsion is studied.
- The effect of emulsifier type and dosage on the rheological properties of cement paste is studied.
- The joint effect of emulsifier and superplasticizer on cement paste is studied.
- Emulsifier can affect the water-reducing effect of superplasticizer on cement.

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ABSTRACT

The workability and mechanical properties of cement asphalt emulsion (CA) mortar are unstable due to the complex interaction between cement and asphalt emulsion. To reveal the interaction between cement and asphalt emulsion, the effect of emulsifier and superplasticizer on the rheology of cement paste and asphalt emulsion is investigated, respectively, and the effect of the interaction between emulsifier and superplasticizer on the rheology of cement paste is studied in this paper as well. Results show that the apparent viscosity and yield stress of asphalt emulsion increase with superplasticizer and emulsifier dosage. Emulsifier can change the yield stress and apparent viscosity of cement paste, and its effect on cement paste differs greatly with the type and dosage of emulsifier. Some emulsifiers can increase the yield stress of cement paste, but some emulsifiers can decrease the yield stress of cement paste. Emulsifier has interaction with superplasticizer, thus affecting the reducing water effect of superplasticizer on cement paste. There is a competition relationship between emulsifier and superplasticizer when they are adsorbed by cement particles. The mixing method, in which superplasticizer is mixed with cement before emulsifier added, is beneficial to obtain a lower apparent viscosity of cement paste for all tested emulsifiers.

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1. Introduction

Currently, the high-speed rail network is in a continuous process of growth in the world. Most of the current high-speed railway tracks prefer non-ballast slab track due to its series of advantages such as low maintenance, low structure height, high availability, and so on [1]. Fig. 1 shows a typical non-ballast slab track. The non-ballast slab track is composed of reinforced pre-stressed concrete slab, concrete roadbed, and cement asphalt emulsion mortar (CA mortar), in which CA mortar acts as elastic absorber and even-adjusting layer between concrete slab and concrete roadbed. For these reasons, CA mortar plays a key role in slab track.

CA mortar is grouted into the chamber between slab track and concrete base in placement. Therefore, a good and stable workability is a key for the successful application of CA mortar. However, it is difficult to control the workability and mechanical properties of CA mortar due to the complex interaction between cement and asphalt emulsion. In the view of asphalt emulsion, the demulsifying rate is accelerated and the formation process of asphalt membrane is affected by cement hydration [2–5]. As for cement, both the rheology and hydration rate of cement are affected by asphalt emulsion [6,7]. Any effect on cement and asphalt emulsion results in a change of workability, and furthermore affects the mechanical

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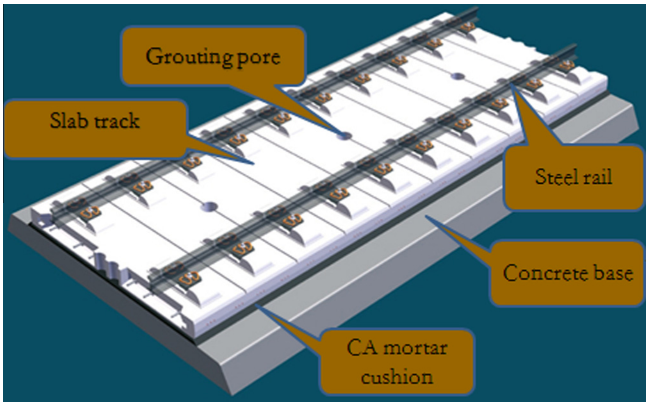

Fig. 1. Structure of slab track.

properties of hardened CA mortar. Revealing the interaction between cement and asphalt emulsion is very vital to control the unstable properties of CA mortar.

CA mortar consists of cement, asphalt emulsion, fine aggregate (sand), water, superplasticizer, and other chemical admixtures. There are at least two particles (asphalt droplets and cement particles) and two surfactants (emulsifier and superplasticizer) in CA paste. Although many studies focusing the effect of every ingredient in CA paste on the rheological behavior of CA paste as well as the corresponding mechanism have been published [3–16], few of them can reveal the complex interaction between cement and asphalt emulsion. Besides, there are two types of CA mortar in non-ballast slab track. One is high-strength CA mortar, in which anionic emulsion is used and asphalt emulsion to cement ratio (AE/C) is low. The other is low-strength CA mortar, in which cationic emulsion is used and AE/C is high. The rheological properties of CA mortar differ greatly when changing the employed asphalt emulsions, emulsion dosage, and the mixing method [6,11,15,16]. Surfactants play an important role in the properties of fresh CA paste. To reveal the complex interaction between cement and asphalt emulsion, it should be understood both the individual and joint effect of emulsifier and superplasticizer on asphalt droplets and cement particles. Different emulsions have different emulsifiers, thus their interactions with cement and superplasticizer vary greatly. The complex interaction between cement and asphalt emulsion in fresh CA paste includes essentially the effect of emulsifier and superplasticizer and their interaction in CA paste. Revealing it is very vital to control the unstable properties of CA mortar.

Because the rheological properties of suspension can not only reveal the inherent properties of suspension system, such as colloidal forces, thixotropy, particles interaction, and particles morphology [20], but also be relevant with the workability. The flow time of a cone flow test is related to apparent viscosity [21–24]. The flowability of cement paste can be improved by decreasing its apparent viscosity. The segregation resistance of course particles is dependent on both the yield stress and apparent viscosity of paste [25,26]. Therefore, the rheological properties can be used to investigate the workability of paste and the particles interaction in suspension.

This paper aims to study the effect of emulsifier and superplasticizer and their interaction in CA paste through rheology study. To achieve the goal, the effect of superplasticizer on the rheology of cement paste and asphalt emulsion is firstly studied, respectively. Secondly, the effect of emulsifier on the rheology of cement and asphalt emulsion is investigated, respectively. Thirdly, the effect of the interaction between emulsifier and superplasticizer on the rheology of cement paste is explored. Finally, a method is proposed to improve the interaction between emulsifier and superplasticizer.

2. Experimental program

2.1. Materials and mix proportions

Tap water, ordinary Portland cement P.O42.5R, polycarboxylate-based superplasticizer, and organic silicon defoaming agent are used in the experiment. The chemical and mineral components of P.O42.5R cement are shown in Table 1 and Table 2, respectively. Two commercial anionic emulsifiers (A1, A2) and two commercial cationic emulsifiers (C1, C2) are employed in the experiment. A1 and C1 are provided by Jinyang road material technology development Co., Ltd. in Jiangsu, China. A2 and C2 are provided by Meadwestvaco Co. in Shanghai, China. The four emulsifiers are all slow-setting emulsifier. Three slow-setting anionic asphalt emulsions and three slow-setting cationic asphalt emulsions are manufactured by A1 and C1, respectively. The mix proportions for manufacturing theses asphalt emulsions are shown in Table 3. The emulsifier dosages are respectively 3%, 3.5%, and 4.5% in the three anionic emulsions and three cationic emulsions. The asphalt emulsions in Table 3 are used to study the effect of emulsifier on the rheology of asphalt emulsion.

The mix proportions of cement pastes in Table 4 are to study the effect of superplasticizer (SP) on the rheology of cement paste.

Table 1
Chemical components of P·O42.5R cement.

Chemical composition	CaO	SiO_2	Al_2O_3	MgO	SO_3	Na_2O
Wt%	61.13	21.45	5.24	2.08	2.05	0.77

Table 2
Mineral components of P·O42.5R cement.

Mineral composition	C3S	C2S	C3A	C4AF
Wt%	46.62	26.32	8.99	8.78

Table 3
Mix proportions for manufacturing asphalt emulsions.

Emulsifier type	Asphalt content (%)	Water content (%)	Emulsifier dosage (%)
C1	60	37.0	3.0
C1	60	36.5	3.5
C1	60	35.5	4.5
A1	60	37.0	3.0
A1	60	36.5	3.5
A1	60	35.5	4.5

Table 4
Mix design for cement pastes with only superplasticizer.

Mix	Cement	Water	Superplasticizer dosage (%)				
Cement paste with SP	1	0.35	0	0.5	1	1.5	2

Table 5
Mix design for asphalt emulsions with superplasticizer.

Mix	Asphalt emulsion	Water	Superplasticizer dosage (%)		
Asphalt emulsion C1 with SP	1	0.35	0	1	2
Asphalt emulsion A1 with SP	1	0.35	0	1	2

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