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Study of the rheological behavior of fresh cement emulsified asphalt paste

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HIGHLIGHTS

- The range of shear rate corresponding practical engineering was calculated.
- The shear thinning behavior and viscosity of fresh cement emulsified asphalt paste were investigated.
- The high content of asphalt emulsion and SP, low solid volume fraction decreased the shear thinning behavior and viscosity.
- The adsorption of SPs on cement and asphalt particles improved the rheological properties.
- Polycarboxylate superplasticizer was more effective than the polynaphthalenesulfonate one.

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ABSTRACT

Cement emulsified asphalt (CA) paste is a suspension with organic and inorganic components, whose rheological behavior is more complicated than that of plain cement paste. The placement quality of CA mortar cushion layer of ballastless track is strongly influenced by its rheological behavior. In this paper, the shear conditions of construction of CA mortar in practical engineering were characterized, and effect of important parameters on its rheological behavior (specially focus on shear rate in practical engineering) was investigated, including solid volume fraction (V_s), mass ratio of asphalt to cement (A/C), and superplasticizer (SP) type and dosage. Pastes were proportioned with A/C of 0.3, 0.5, 0.7 and 0.9, various V_s of 30%, 40%, 50% and 60%, and SPs of polycarboxylate (PCA) and polynaphthalenesulfonate (PNS). Rheological curves were measured at 25 °C, using a rotating coaxial cylinder viscometer. Results indicate that most of the CA pastes are shear thinning flow in the shear rate range of practical engineering. The shear thinning behavior is slacked down with the decreasing of V_s, increasing of A/C and concentration of SPs. Severe shear thinning behavior maybe not good for the placement quality of CA mortar cushion layer.

1. Introduction

The modification of Portland cement based materials with asphalt emulsion is widely used in asphalt modified concrete [1] and cement emulsified asphalt (CA) mortar [2]. It allows improving many properties of fresh and hardened cement-based materials such as rheology, elasticity, flexural strength, dynamic mechanical property, fatigue property and durability [3,4]. Slab track systems of types CRTS I and CRTS II have been developed in China (Fig. 1), which have been widely used in high speed railway in China. CA mortar is used in the slab track systems as a cushion layer, which fulfills important structural functions [2]. It consists of cement, asphalt emulsion, aggregate, water and other admixtures.

During the construction of cushion layer, fresh CA mortar is grouted into the chamber between the concrete roadbed and track slab (CRTS I and CRTS II) on site. The site inspection revealed that cushion layers sometimes showed certain defects, including bubble floating and aggregate sedimentation, etc., especially the region near perfusion port (Fig. 1). This might be related within stability of solid particles and bubbles in CA mortar because of high water to cement ratio (normally <0.85 for CRTS I and <0.58 for CRTS II), and has a detrimental influence on the dynamic mechanical property, fatigue property and durability of cushion layer [5,6]. It is widely accepted that the instability of solid particles and bubbles in suspension mainly depends on its rheological property [7,8].

Due to the adding of asphalt emulsion, fresh CA mortar is a very complicated suspension with organic and inorganic particles,

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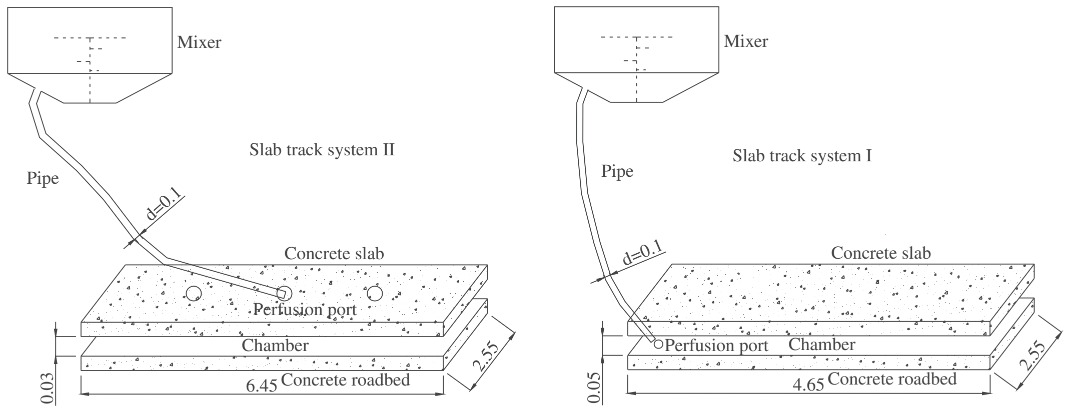

Fig. 1. Geometry and dimensions (in meters) of the slab track system (II and I) and the pouring procedure.

whose particle size ranges from several μm to cm. Only few publications were dealing with the rheological behavior of CA mortar. Wang et al. [9] had studied the rheological behavior of CA paste, who pointed out that CA mortar was shear thinning flow in the shear rate range of 0–150 s^{-1}, and its rheological properties were influenced by the addition of thickener and silica fume, and A/C ratio. Zhang et al. [10] had studied the influencing factors of type of asphalt emulsion, asphalt emulsion content, temperature, and shelf time on the yield stress of CA paste, who pointed out that the yield stress was increased with shelf time, decreasing of A/C and cationic emulsified asphalt, and established a generalized model linking yield stress and relative hydration degree. Hu et al. [11] had found that both anionic and cationic asphalt droplets exhibited favorable adsorption onto cement grain surface by adopting a particle size analyzer, and the cement to asphalt emulsion ratio and types of asphalt emulsion had high influence on the particle size in the CA paste.

However, the viscosity of CA paste at different shear rates did not receive enough attention, especially the viscosity at the shear rate in practical engineering. The probability of instability of solid particles and bubbles in suspension depends on the yield stress, but the velocity of which is determined by viscosity, especially in shear [7,8].

In order to avoid the segregation of CA mortar during casting, the viscosity has to be controlled at a certain range. In view of the shear thinning behavior of CA mortar, two methods can be applied. Firstly, one can increase the viscosity of CA mortar on the whole shearing range by using viscosity-enhance agents, as shown in the curve-S2 of Fig. 2. In this case, the mold filling ability would be impaired, which may lead to an incompleted cushion layer. Secondly, one also can decrease the intense of shear thinning, but keep the viscosity of CA mortar is higher than the viscosity at the highest shear rate of practical engineering, as shown the curve-S3 of Fig. 2). This is the desired scenario.

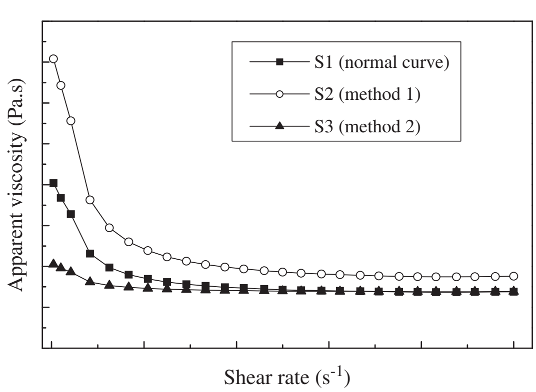

Fig. 2. Two methods to avoid the segregation of CA mortar during casting.

Therefore, to control the viscosity of CA mortar at a certain range is crucial to the quality of CA mortar cushion layer. In this paper, the shear region corresponding with the practical engineering is firstly worked out, and the rheological behavior of CA paste along with their shear rate is studied in this paper. In view of constitution characteristics of this material and some conventional methods to modify the rheological properties of cement based paste, this paper studies the effect of following factors on rheology of CA paste: (1) the effect of solid volume fraction V_s (the sum of asphalt droplet and cement particle), (2) the effect of asphalt to cement ratio A/C, (3) effect of SPs, and (4) effect of type of emulsified asphalt.

2. Experimental program

2.1. Materials

A cationic and an anionic emulsions were used for study. The cement was type I Portland cement, complied with the requirements of ASTM C150 [13]. Experiments were carried out with various V_s of 30%, 40%, 50% and 60%, various A/C of 0.3, 0.5, 0.7 and 0.9, and SP of PNS and PCA. The chemical and physical properties of cement are given in Table 1. The physical properties of two asphalt emulsions are given in Table 2. The particle size distribution of cement and asphalt particles is given in Fig. 3.

A PNS with solid content of 30% and specific gravity of 1.11, as well as a PCA with solid content of 30% and specific gravity of 1.07 were used in this investigation. Water in the SP and asphalt emulsion was accounted to calculate V_s.

Table 1
Chemical and physical properties of cement.

Chemical composition (wt.%)	
SiO_2	21.20
Al_2O_3	5.43
Fe_2O_3	3.87
CaO	65.66
MgO	0.87
SO_3	0.91
Ignition loss	2.5
Physical properties	
Blaine specific surface properties (m^2/kg)	338
Mean particle diameter (μm)	16.98
Setting time (min)	
Initial set	96
Final set	133
Water content for standard consistence (%)	24.5
Soundness	Satisfied