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Effect of mass ratio of asphalt to cement on the properties of cement modified asphalt emulsion mortar

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HIGHLIGHTS

- CRTSI type CEAM with modifier was investigated.
- A/C ratio significantly affect flow time, air content and mechanical properties of CEAM.
- Type of modifier and its dosage both affect the properties of CEAM.

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ABSTRACT

This study evaluated the effects of two types of cationic modified asphalt emulsions, i.e. SBS modified asphalt emulsion and SBR modified asphalt emulsion, on the flow time, air content and mechanical properties of cement emulsified asphalt mortar (CEAM) at varying asphalt to cement (A/C) ratios. The flow time and air content of fresh CEAM were measured, and the compressive strength, elastic modulus and impact toughness of hardened CEAM were tested. The experimental results show that the flow time, air content and toughness increase with the increase of A/C ratio, while the compressive strength and 28d elastic modulus show a different trend. The effects of modifiers on the properties of CEAM are different. The flow time, air content and toughness increase with the SBS content, while the compressive strength and 28d elastic modulus show the opposite trend. Contrary to the toughness, the flow time, air content, compressive strength and 28d elastic modulus decrease with the SBR content.

1. Introduction

CRTSI type slab track structure is one of the track systems implemented in high-speed railway in China. Cement emulsified asphalt mortar (CEAM) is a key component in the ballastless slab track and serves as the leveling and shock-absorbing material between the track slab and concrete base [1]. CEAM for CRTSI type structure is a viscoelastic material composed by cement, sand, cationic emulsified asphalt, water and a variety of admixtures [2].

Due to the presence of asphalt, CEAM exhibits quite different properties from cement mortar [3]. Besides the properties of raw materials [4], mix parameters, such as A/C ratio, W/C ratio and sand-cement (S/C) ratio, play a significant role in the properties of CEAM. Recently, many researches have been carried out on the effects of A/C ratio on the properties of CEAM.

Tian et al. [5] studied the relationship between elastic modulus and composition parameters of cement-asphalt materials, and found that A/C ratio is a key factor affecting the mechanical properties. Wang et al. [6] investigated the factors influencing the strength of CEAM, and reported the importance of raw materials follows the order of cement, asphalt emulsion and sand. Liu et al. [7] studied the static and dynamic mechanical behaviors of CEAM, and found that the compressive strength, elastic modulus and damage energy of CEAM decreased with the increasing of A/C ratio. Wang et al. [8,9] investigated the factors influencing the compressive strength and microstructure of CEAM, the test results indicated that A/C ratio had significant influence on the compressive strength and its developing trend. The influence of loading rate on the mechanical properties of CEAM was studied by Kong et al. [10], and the results indicated that the peak strength and elastic modulus of CEAM with lower A/C ratio were obviously higher than those of CEAM with higher A/C ratio. The former was characterized by brittleness, while the later was seen as a tough material. Wang et al. [11] studied the influence of A/C ratio on the fracture toughness of CEAM, and the results indicated that both strength and fracture energy of CEAM were closely related with A/C ratio, the strength of CEAM decreased and the deformability (ductility)

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increased with the increase of A/C ratio, and thus the fracture mode of CEAM experienced a transition from quasi-brittle fracture to ductile fracture with the increase of A/C ratio. Wang et al. [12] evaluated the effects of A/C ratio on the properties of two types of CEAM, the results indicated that the workability and compressive strength of CEAM dramatically decreased with the increase of A/C ratio, and CEAM with cationic asphalt emulsion has worse workability than that of anionic asphalt emulsion. Ouyang et al. [13] studied the rheology of fresh cement asphalt pastes with various A/C ratios, and the results indicated that the viscosity and yield stress of cement asphalt pastes change with A/C ratio. When the viscosity remains constant, the yield stress of cement asphalt pastes decreases quickly with the increasing A/C from 0 to 0.4, and then increases slightly with A/C from 0.4 to 1.0.

The asphalt is often modified by polymer to overcome its original drawbacks [14–17], more specifically, the toughness and durability of CEAM are often improved by polymer when applied in the cold area. However, few researches have been carried out on the effect of the type of asphalt emulsion on the properties of CEAM. Therefore, two types of modified asphalt emulsion were used to produce CEAM at different A/C ratios and the effects of A/C ratio on the flow time, air content and mechanical properties (compressive strength, elastic modulus and impact toughness) of CRTSⅠ type CEAM were studied in this paper.

2. Experimental programs

2.1. Materials

An asphalt emulsion was obtained by first modifying type 70# asphalt with SBS and then emulsifying the modified asphalt with cationic emulsifier. Another asphalt emulsion was produced by first emulsifying type 70# asphalt with cationic emulsifier and then mixing with SBR latex. The properties of type 70# asphalt were shown in Table 1, and the properties of two types of asphalt emulsions meet the requirements of Chinese specification [18], and the solid content was controlled at about 60%.

Type 52.5R Portland cement and siliceous sand were pre-mixed as dry mix. The mass ratio of cement to sand is 1:3. 28d compressive strength of the cement was 54.5 MPa. The fineness modulus of sand was 1.6, and its size distribution are as follows: 0.075–0.15 mm accounted for 7.5% (mass fraction), 0.15–0.30 mm accounted for 38.5%, 0.3–0.6 mm accounted for 38.5%, 0.60–1.18 mm accounted for 15.5%. The properties of dry mix meet the requirements of Chinese specification [18].

2.2. Mixing and curing

A high-speed shear mixer was used to mix CEAM mixture at ambient temperature. Asphalt emulsion and water were added in the mixer and mixed slowly for 1 min, and then dry mix was added within 30 s. The mixture was mixed slowly for 1 min, followed by 2 min for quick mixing, and finally mixed slowly for another 30 s in order to expel the bubbles in the mixture. The specimens were demolded after 24 h, and then cured in a standard curing room (temperature 20 ± 3 °C, RH ⩾ 65%).

Table 1
Properties of type 70# asphalt.

Properties	Unit	Value
25 °C penetration	0.1 mm	68.2
15 °C ductility	cm	>100
Softening point	°C	49.0
Specific gravity	g/cm^3	1.01

2.3. Experimental methods

The flow time, air content, compressive strength and elastic modulus were tested according to Chinese specification [18]. The flow time was tested by J-funnel. The J-funnel was first filled with fresh mortar, and recorded the time required for the mortar flowing out of the nozzle. The air content was measured by comparing the apparent density and real density. Compressive strength was carried out on the specimens of $\Phi 50 \times 50$ mm.

According to ACI544 [19], a drop hammer impact test method was used to measure the toughness of CEAM. The used specimens were cylinder with dimension of $\Phi 165 \times 65$ mm. When the specimens appeared cracks and damaged, the impact times n were recorded as the indicator of impact toughness.

2.4. Mix proportions

The mix proportions of CEAM were given in Table 2. Water-cement (W/C) ratio was fixed at 0.73, the A/C ratio by weight is ranging from 0.83 to 0.89 according to the practical application of CEAM, and the modifier content changes from 0% to 4%. The mixes presented in Table 2 can meet the mechanical properties of CRTSI type CEAM [18].

3. Results and discussion

3.1. Flow time

The influence of A/C ratio on the flow time of fresh CEAM is shown in Fig. 1. Fig. 1 shows that the flow time of fresh CEAM increases with the increase of A/C ratio, which means that the fluidity of CEAM decreases. The increase of A/C ratio can cause the congregation of cement grains and asphalt emulsion particles, and thus decreases the fluidity of CEAM [12]. The fluidity of CEAM is related with the viscosity of fresh CEAM, when the content of asphalt (A/C ratio) increases, the viscosity of fresh CEAM increases, and the flow time of CEAM increases.

It can also be seen from Fig. 1, the flow time of fresh CEAM with SBS is higher than that of control mortar when the A/C ratio remains the same, higher SBS content and A/C ratio lead to higher flow time. The flow time of fresh CEAM with SBR is lower than that of control mortar when the A/C ratio is the same, and decreases with the SBS content and increases with the increase of A/C ratio. Firstly, the incorporation of SBS and SBR affects the viscosity of asphalt emulsion differently, the Egler viscosity of emulsified asphalt without modifier is 3.1, and emulsified asphalt with 4% SBR is 3.5, and asphalt emulsion with 4% SBS is 5.3. The Egler viscosity of emulsified asphalt increases slightly with the SBR content, and increases obviously with the SBS content. Higher Egler viscosity of SBS modified asphalt emulsion can result in higher yield stress and apparent viscosity of fresh mortar [20], which are detrimental to the fluidity of fresh mortar. Secondly, the particle size distribution of emulsified asphalt is different, the average particle diameter of emulsified asphalt without modifier is 1.71 μm, and emulsified asphalt with 4% SBR is 1.43 μm, but 4% SBS is 5.21 μm. The average particle diameter of emulsified asphalt decreases slightly with the SBR content, and increases obviously with the SBS content. The change of particle diameter of emulsified asphalt caused by the incorporation of the modifier can also affect the fluidity of fresh CEAM. Finally, SBS modified asphalt is difficult to be emulsified, more emulsifier is needed to emulsify asphalt modified by higher dosage of SBS. The increase of emulsifier dosage increases the apparent viscosity and yield stress of fresh mortar [21,22], and thus decreases the fluidity of CEAM with SBS.