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Damping characteristics of cement asphalt emulsion mortars

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HIGHLIGHTS

- Dynamic mechanical analysis (DMA) test was conducted to analyze damping performance.
- Mechanical properties of the mortars were characterized.
- Damping performance was analyzed at different *a*/*c* ratio, frequency and temperature.
- ESEM was adopted to characterize the microstructures of the mortars.

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ABSTRACT

Cement asphalt emulsion mortars are widely used as construction and building materials, such as high speed railways and road pavements. Their damping characteristics are very important to resist vibration and the deformation caused by repeating loads. Therefore, it is of greatly theoretical and practical significance to study the damping performance of the mortars. In this work, dynamic mechanical analysis (DMA) test was innovatively conducted to analyze damping parameters of the mortars, such as loss factor and complex modulus. The environment scanning electron microscope (ESEM) was adopted to characterize the microstructures of the mortars. The mechanical properties of the mortar were characterized by the compressive strength and flexural strength test. The results show that the addition of asphalt emulsion decreases the mechanical properties of the mortar, but the plasticity of the mortar is improved. The higher the asphalt emulsion content is, the higher the loss factor of the mortar is; and the ability of the mortar to resist deformation is stronger. With the increase of temperature, the loss modulus of the mortar decreases, but the loss factor increases. The damping performance of the mortars can be enhanced. The damping performance of cement asphalt emulsion mortar at low loading frequency is higher than that of the mortar at high loading frequency. With the increase of *a*/*c* ratios, asphalt attached to surface of cement hydrates increases. The cement asphalt emulsion mortars with suitable asphalt-cement (*a*/*c*) ratios possess excellent damping performance.

1. Introduction

Cement and asphalt materials are widely used for building construction, bridges, dams and road construction as the cementitious materials of the construction industry. Cement-based materials possess advantages of high strength and corrosion resistance, but they have large rigidity and poor non-deformability. Asphalt materials have strong resistance to deformation, excellent viscoelastic characteristics and damping performance. However, they are easy to bring about permanent deformation under loading actions [1,2]. Cement asphalt emulsion mortars are organic-inorganic composites, which consist of cement, asphalt emulsion, sand and admixtures. The interactions in cement asphalt emulsion mortars include the influence of cement on the process of emulsified asphalt demulsification and the influence of asphalt emulsion on the hydration process of cement [2,3]. The water coming from demulsification of asphalt emulsion can be used for cement hydration. The water can solve the contradiction between "water repellent" of emulsified asphalt demulsification and "water demand" of cement hydration. In contrast to cement-based materials and asphalt-based materials, cement asphalt emulsion mortars can not only combine the advantages of the two materials, but also can make up for the shortcomings of two types of materials [4]. Cement asphalt emulsion mortars are advanced engineering

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materials which getting more and more popular in high speed railway engineering projects [5]. There are two types of cement asphalt emulsion mortars, thyp I with more asphalt and less cement, as well as type II with more cement and less asphalt [6].

Fig. 1 shows the schematic diagram of the ballastless track structure of high-speed railway and position of cement asphalt emulsion mortar layer. The layer is the key structure of ballastless track of high-speed railway. Its main function is to fill, support tracks, bear force from tracks and trains and provide appropriate toughness. The performance of the layer can directly influence the durability of track structure and stability from the running train. The solidification hardening process of cement asphalt emulsion mortars is composed of cement hydration process and asphalt emulsion demulsification process. As an inorganic material, cement mainly displays the stiffness of its material in cement asphalt emulsion mortar. On the one hand, the cement is mixed with asphalt emulsion; and the water in the emulsified asphalt with cement is hydrated to provide strength for the mortars. Due to the viscoelastic energy of asphalt, the plasticity of cement asphalt emulsion mortars can be improved; and the anti-fracture properties of the mortars can be enhanced. After asphalt emulsion demulsification, the water in asphalt emulsion with cement granule is hydrated; and asphalt can permeate in the structure of the cement hydration products. The asphalt encircles with mesh structure packages on the surface of the cement hydration products. Thus the cement hydration can be influenced by asphalt [7].

Damping characteristics refer to the consumption of vibration energy in the material, that is to say, the internal friction of the material. The fundamental principle of damping is the loss of energy and all kinds of damping technology focus on how to transform the stimulated vibration energy into other forms of energy (such as thermal energy, denatured energy, etc.), so as to make the system return to the state before stimulated as soon as possible [8–10]. The cement has certain strength after hydration process; and the emulsified asphalt after demulsification process can provide toughness for the materials. The combination of these two materials makes cement asphalt emulsion mortars with good damping characteristics [11–13]. Wang, et al. [14] studied damping characteristics of cement asphalt emulsion mortars and the result shows that the energy dissipation coefficient of cement asphalt emulsion mortar is relatively stable with the change of loading stress, varying from 13% to 15%. With the increase of test temperature, the energy dissipation coefficient of cement asphalt emulsion mortars increases a lot at low loading frequency but increases a little at high loading frequency. In order to obtain higher damping ratio, the ultimate strength is usually sacrificed. Chen, et al. [15] designed the damping capacity of crumb rubber concrete and found that the damping ratio increases with the reduction of compressive strength and the damping capacity decreases with the extension of age.

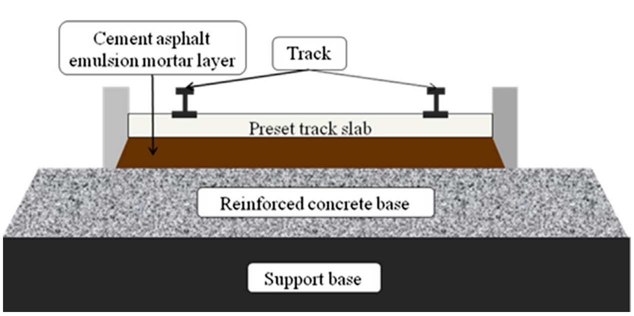

Fig. 1. Schematic diagram of railway ballastless track structure.

Table 1
Tests for cement asphalt emulsion mortar.

Asphalt-cement (a/c) ratios and sample sizes	Laboratory tests	Test settings
0, 0.17, 0.20, 0.23, 0.26; 40 mm × 40 mm×160 mm	Mechanical test	Compressive strength test (2.40kN/s, 20 °C); flexural strength test (0.05kN/s, 20 °C)
0, 0.17, 0.20,0.23, 0.26; 5 mm × 15 mm×35 mm	Damping test	2, 4, 6, 8, 10 Hz loading frequency; −20–50 °C
0.17, 0.20, 0.23, 0.26; 5 mm × 3 mm	Microscopic analysis	Environmental scanning electron, 3.0 kV, 20 °C

The damping property of cement-based materials can be affected by the flexural strength, aggregate and maintenance environment of cementitious materials [4]; and it relates to the compressive strength [16]. The shape and the size of aggregate affect the elastic modulus of the system; and the coarse aggregate can lead to the increase of elastic modulus on the later stage and the decrease of damping ratio [17]. The curing environment has a significant influence on damping coefficient and the sensitivity. Damping capacity of the test block under drying condition is higher than humid environment [18]. The damping ratio of curing test block in water is 1.55 times than curing test block in the curing room [19].

In this work, the dynamic mechanical tests of cement asphalt emulsion mortars with different asphalt-cement ratios were carried out. The tests of cement asphalt emulsion mortar are listed in Table 1. The changes of the loss factor with temperature under different frequencies were analyzed by DMA dynamic mechanical test. The microstructure of cement asphalt emulsion mortar was characterized with the environment scanning electron microscope (ESEM). The effects of asphalt and cement on mechanical properties of the cement asphalt emulsion mortar and the interactions between cement and asphalt emulsion were deeply interpreted. It is greatly significant to promote cement asphalt emulsion mortars to be widely used in construction and building engineering.

2. Materials and experiments

2.1. Raw materials

Ordinary Portland cement as well as Portland cement with higher strength grade and sulphoaluminate cement with higher early strength can be used in cement asphalt emulsion mortars [6]. In this work, ordinary Portland cement was used and its properties are shown in Table 2. The properties of asphalt binder are shown in Table 3. The properties of defoamer are shown in Table 4. Dry sand passing through 1.18 mm sieve was used and its apparent density is 2.610 g/cm^3. Tap water was used for mixing.

2.2. Preparation of cement asphalt emulsion mortars

The cement asphalt emulsion mortar proportions are shown in Table 5. Five different asphalt – cement (a/c) ratios, 0, 0.17, 0.0.20, 0.0.23 and 0.26, were designed to prepare cement asphalt emulsion mortar specimens in this work. The water – cement ratio (w/c) adopts 0.4, sand – cement (s/c) ratio adopts 1.2. For each mortar mixture, three duplicate samples were prepared (see Table 6.).

Firstly, asphalt emulsion with evaporated residue content of 58.0% was prepared. Dry materials, such as cement and sand, were mixed uniformly in a mixer; then asphalt emulsion and water were added into dry materials to obtain wet mixtures. Then the mixer with 20 r/min – 30 r/min mixing speed was adopted to mix the mixtures for 5 min. At the same time, defoaming agent with water mass of 2.0% was added to the mixtures to avoid the formation of more bubbles. Finally, the mortar mixtures were poured into steel moulds for maintenance. After 24 h, the mortar specimens were demoulded. The specimens were cured for 3, 7 and 28-curing days at the environment with temperature of 20 °C and the relative humidity of 90%. The flow chart of cement asphalt emulsion mortar preparation is shown in Fig. 2.