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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.

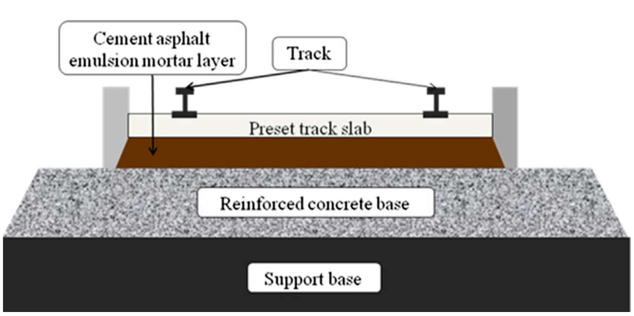

Fig. 1. Schematic diagram of railway ballastless track structure.

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.

Table 2
Properties of the Portland cement.

Properties	Results
Density (g/cm^3)	2.923
Mean diameter size/μm	20.689
3 day compression strength/MPa	23.9
28 day compression strength/MPa	48.5
Specific surface area/(m^2/kg)	328
CaO content (%)	59.21
SiO_2 content (%)	25.93

Table 3
Properties of asphalt binder.

Properties	Specification [20]	Results
Needle penetration (25 °C,100 g, 5 s) (0.1 mm)	80–100	88
Ductility (5 °C,5cm/min) (cm)	≥40	47
Soften point (°C)	≥50	53.4
Density (15 °C, g/cm^3)	–	1.036
Wax content (%)	–	1.4
Flash point/°C	≥230	284

Table 4
Properties of defoamer.

	Properties	Results
1	Appearance	Milky white liquid(at room temperature)
2	Solid content (%)	60%
3	pH	7.3
4	Stability	No stratification and no precipitation for 18 min by 2800r/min centrifuge test

2.3. Mechanical test

The mechanical strength test of cement asphalt emulsion mortar was carried out by using TYE-300D cement mortar flexure and compression test machine. The loading rate of the compressive and flexural tests is 2.40 kN/s and 0.05 kN/s, respectively [3]. The dimensions of tested specimens are 40 mm × 40 mm × 160 mm. And the specimens were tested at the environment with the temperature of 20 °C.

2.4. Damping test

Fig. 3 shows the view of dynamic mechanical analysis test. The damping performance test of cement asphalt emulsion mortar was conducted by DMA Q800. According to the environmental temperature in the actual engineering of the mortars, The damping test was controlled by the liquid nitrogen cooling at −20–0 °C temperature and the electric heating at 20–50 °C temperature. Loading frequency was selected at ranges of 2–10 Hz [21]. The double cantilever beam clamp was chosen as the loading clamp as to the force of the specimen.

Cement asphalt emulsion mortar specimens cured for 28 days were used for damping test. The mortars were cut into 35 mm × 15 mm × 5 mm size specimens by angle grinder and the testing specimens were obtained by sanding the surface with sand paper. Experiments were conducted at five different frequencies of 2, 4, 6, 8 and 10 Hz for different proportions of cement asphalt emulsion mortar specimens. The amplitude used for specimen test was 10 μm.

2.5. Micro structure characterizations

In this work, the microstructure of cement asphalt emulsion mortars was characterized by S-4800 environmental scanning electron microscope (ESEM). Specimens of cement asphalt emulsion mortars prepared for 28 days were selected for sample preparation. The specimen was broken into small pieces of about 5 mm in diameter and the thickness was not more than 3 mm. The experimental specimen surface was sprayed and coated by gold to improve specimen conductivity. The temperature of SEM test was 20 °C.

3. Results and discussion

3.1. Mechanical properties of cement asphalt emulsion mortars

With the addition of asphalt emulsion, the mechanical strength of the mortars decreases. As to Fig. 4, it's obvious that the stress-strain curves peak gradually decreases and the trends flatten with the increase of asphalt emulsion content. Under the same strain level, the higher the asphalt emulsion content is, the less stress endured the same strain of the specimen is; the deformation ability of the mortars can be improved. Therefore, the deformation and the plasticity of cement asphalt emulsion mortar increases.

The mechanical strength of cement asphalt emulsion mortar is enormously affected by the contents of cement and asphalt emulsion [22]. Figs. 5 and 6 show that the compressive strength and the flexural strength of the mortars are evidently reduced when the asphalt emulsion is incorporated in the mortars. The compressive strength of the mortar is one half that of the control group; and the flexural strength of the mortar is about two thirds that of the control group. The 28-day compressive strength and flexural strength of the mortars with *a*/*c* ratio of 0.26 is the lowest. It's 14.1 MPa and 4.0 MPa, respectively. However, the compressive strength and the flexural strength of the mortars can meet the instruction requirements [3].

The asphalt belongs to the polymer material; and it exists with chains or reticular structure in asphalt [23]. The viscosity of the asphalt makes the mortar deform under external force. When the asphalt emulsion is added into the cement mortar, the chain or the reticular structure of asphalt molecular can be mingled with the cement hydration products. When the external force act on,

Table 5
Cement asphalt emulsion mortar proportions.

Groups	Cement	Asphalt emulsion	Sand	Water	*a*/*c*
1	525	158	630	143	0.17
2	507	177	609	128	0.20
3	492	197	590	114	0.23
4	477	215	575	100	0.26
5	657	–	786	262	0.00

Table 6
Complex modulus of the mortars at different frequencies and *a*/*c* ratios.

Frequency/Hz	2 Hz	4 Hz	6 Hz	8 Hz	10 Hz
a/*c* ratios	Complex modulus/MPa	Complex modulus/MPa	Complex modulus/MPa	Complex modulus/MPa	Complex modulus/MPa
0.00	4986.58	5098.37	5179.87	5219.37	5386.77
0.17	4217.26	4352.99	4587.33	4792.60	4953.66
0.20	3921.79	4002.38	4187.65	4320.68	4532.70
0.23	3767.34	3825.95	3988.21	4032.96	4176.44
0.26	3153.21	3226.06	3278.35	3367.80	3608.32

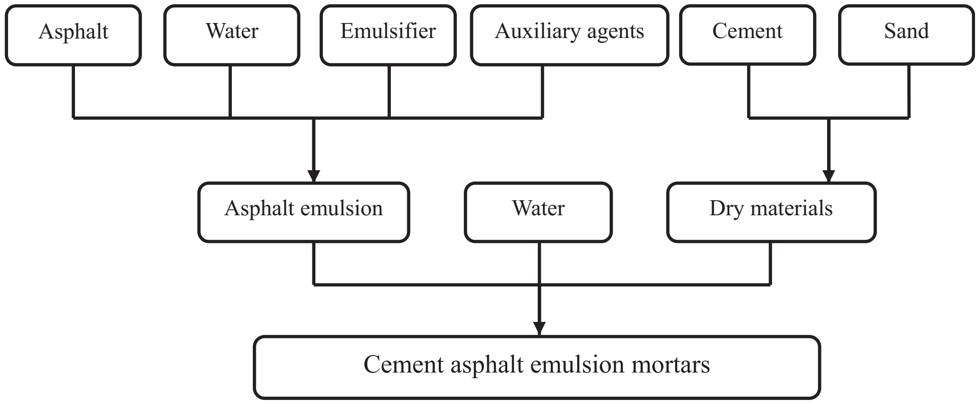

Fig. 2. The flow chart of cement asphalt emulsion mortar preparation.

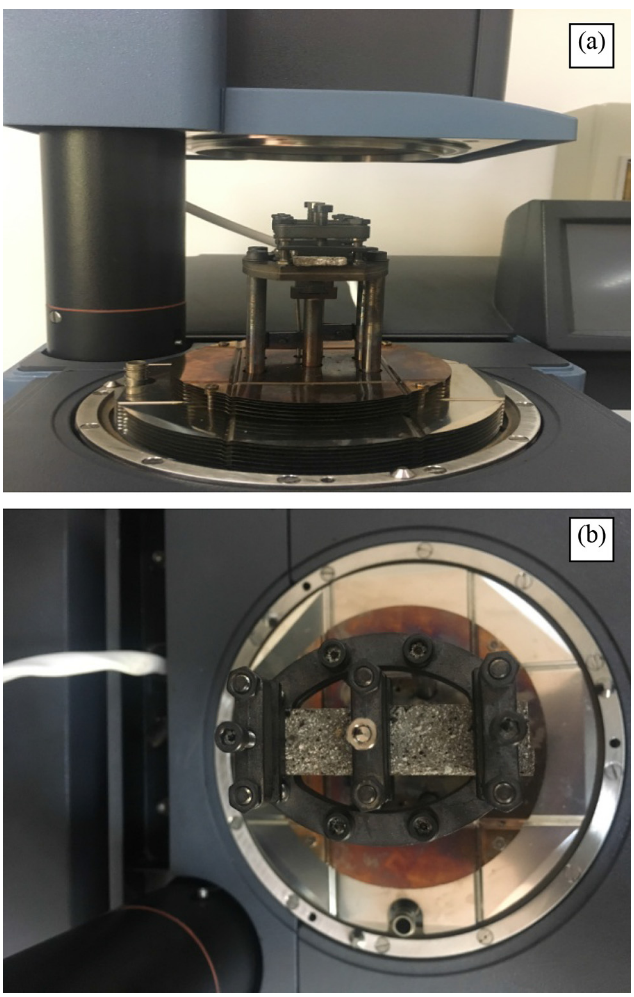

Fig. 3. Dynamic mechanical analysis test: (a) front view and (b) top view.

the compressive strength and flexural strength of cement asphalt emulsion mortar can be lower than the control group because of the existence of asphalt.

3.2. Damping property of cement asphalt emulsion mortars

3.2.1. Loss factors of the mortars at different frequencies and a/c ratios

Dynamic mechanical analysis is the mechanical behavior of viscoelastic material under cyclic stress (or strain). Dynamic mechan-

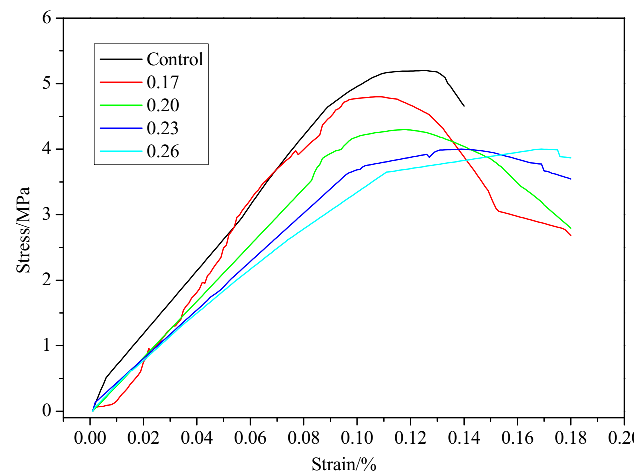

Fig. 4. Stress-strain curves of the mortars with different *a*/*c* ratios.

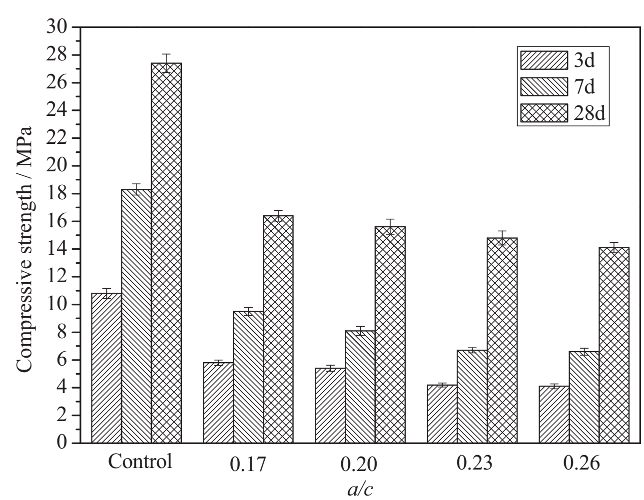

Fig. 5. Compressive strength of the mortars with different *a*/*c* ratios.

ical analysis can determine the dynamic mechanical properties of materials in a certain temperature range and frequency range. It is an important mean to study the viscoelastic performance of materials. The complex modulus is expressed as Eqs. (1) and (2):

$$E^{*} = \frac{\sigma}{\varepsilon} = \frac{\sigma_0}{\varepsilon_0} e^{i\alpha} = E(\cos\theta + i\sin\theta) \tag{1}$$

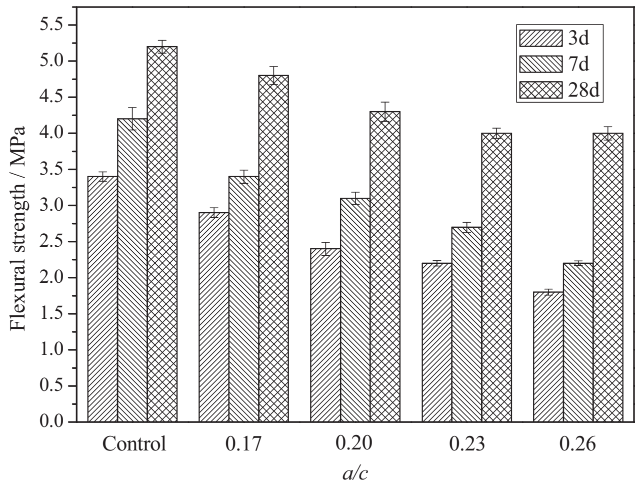

Fig. 6. Flexural strength of the mortars with different a/c ratios.

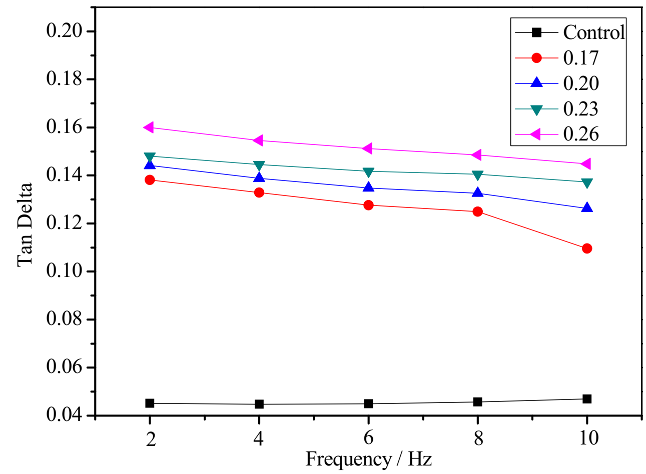

Fig. 7. Loss factor changes of the mortars at different frequencies.

$$E^* = E' + iE'' = E'(1 + i\eta) \quad (2)$$

where the E^* is complex modulus; the θ is the phase angle difference of strain hysteresis stress, which is expressed as Eq. (3).

$$\eta = \tan\theta = \frac{E\sin\theta}{E\cos\theta} = \frac{E''}{E'} \quad (3)$$

where the η is the loss factor of viscoelastic damping material; it is one of the main indicators of dissipation of vibration energy damping materials. The results of the mortars at different frequencies and a/c ratios are shown in Table 5.

As shown in Fig. 7, the loss factor value of the mortars decreases with the loading frequency increases. The mortars need more internal energy to resist the energy loss for the high loading frequencies. Cementitious mortars with viscoelastic materials of asphalt emulsion, the maximum loss factor of the mortars with different a/c ratios are 0.161, 0.148, 0.145 and 0.139, respectively. The maximum loss factor of the control group is 0.047. It's obvious that cement mortar without asphalt emulsion incorporation is almost not influenced by the change of the frequency. The loss factor of cement asphalt emulsion mortar shows a decreasing trend with the increase of loading frequency. The decreasing trend of the loss factor curve is more and more gradual with the increase of the asphalt emulsion content.

The viscoelasticity of the material is that the material can be elastic and viscous at the same time under the small stress. In contrast to the ideal elastic strain, the stress and strain of elastic materials don't lag behind time; while the viscous materials can lag behind time. The complex modulus E^* can indicate the viscoelasticity of the mortar. The complex modulus of the real part indicates that the strain energy of the material, which is the energy storage modulus E'. The complex modulus of the imaginary part tells the heat energy of the material, which is the loss modulus E''.

The damping performance shows the dissipation energy of materials in motion; and the loss modulus E'' in the complex modulus E^* shows the damping performance of the materials. The higher loss factor η is, the better damping performance is. It indicates that the damping performance of the mortar can be improved in that the viscoelasticity of asphalt emulsion can enhance the dissipation capacity of the mortar.

When the loading frequency is constant, the higher the asphalt emulsion content in the mortars is, the higher the storage modulus is; and the energy dissipation capacity of the mortars is stronger. It indicates that asphalt emulsion can reduce the rigidity of the mortars. Therefore, the ability of cement asphalt emulsion mortars to resist deformation is enhanced.

When the content of asphalt emulsion is constant, the higher the loading frequency of the test is, the higher the loss modulus of the mortar is. As shown in Tab.6, the complex modulus of the mortar decreases with the increase of asphalt emulsion content. The energy dissipation capacity of the mortar is used to ward off energy loss. As a result, the loss factor decreases; and the loss factor of the mortar decreases as well. Damping performance of the mortar at low frequencies is obviously higher than that of the mortar at high frequencies. The higher the frequency is, the more the mortar needs to resist; and the larger the complex modulus of the mortar is. With the addition of asphalt emulsion, the complex modulus decreases and the loss factor of the mortar increases. The damping performance of the cement asphalt emulsion mortars is improved.

3.2.2. Loss factors of the mortars at different temperature and frequencies

Fig. 8 shows the loss factor changes of the mortar at different frequencies. It can be seen that the external frequency has an attenuation effect on the cement asphalt emulsion mortar loss factor. The peak of the loss factor decreases gradually with the increase of frequency (2–10 Hz). The loss factor of the mortars at 10 Hz frequency is reduced by 1.07, 1.1, 1.13 and 1.27 times that of the mortars at 2 Hz frequency. The addition of asphalt emulsion can increase the viscoelasticity of the mortars; and the damping performance of the mortar can be improved with the increase of plasticity.

The addition of asphalt emulsion delays the hydration of cement and reduces the mortar stiffness. The asphalt coming from asphalt emulsion demulsification can increase viscoelasticity of cement asphalt emulsion mortars. Therefore, the cement asphalt emulsion mortar exhibits a certain viscoelasticity at low loading frequency or static load condition; and the loading frequency has a great influence on the loss factor of the mortars.

At the same time, peak of loss factor gradually becomes widen with the increase of loading frequency; and curve gradually levels off. The changes show that the loss factor exists a higher increase at low loading frequencies and a lower increase at high loading frequencies for the mortar. The damping performance of cement asphalt emulsion mortar at low loading frequencies is higher than that of the mortars at high frequencies.

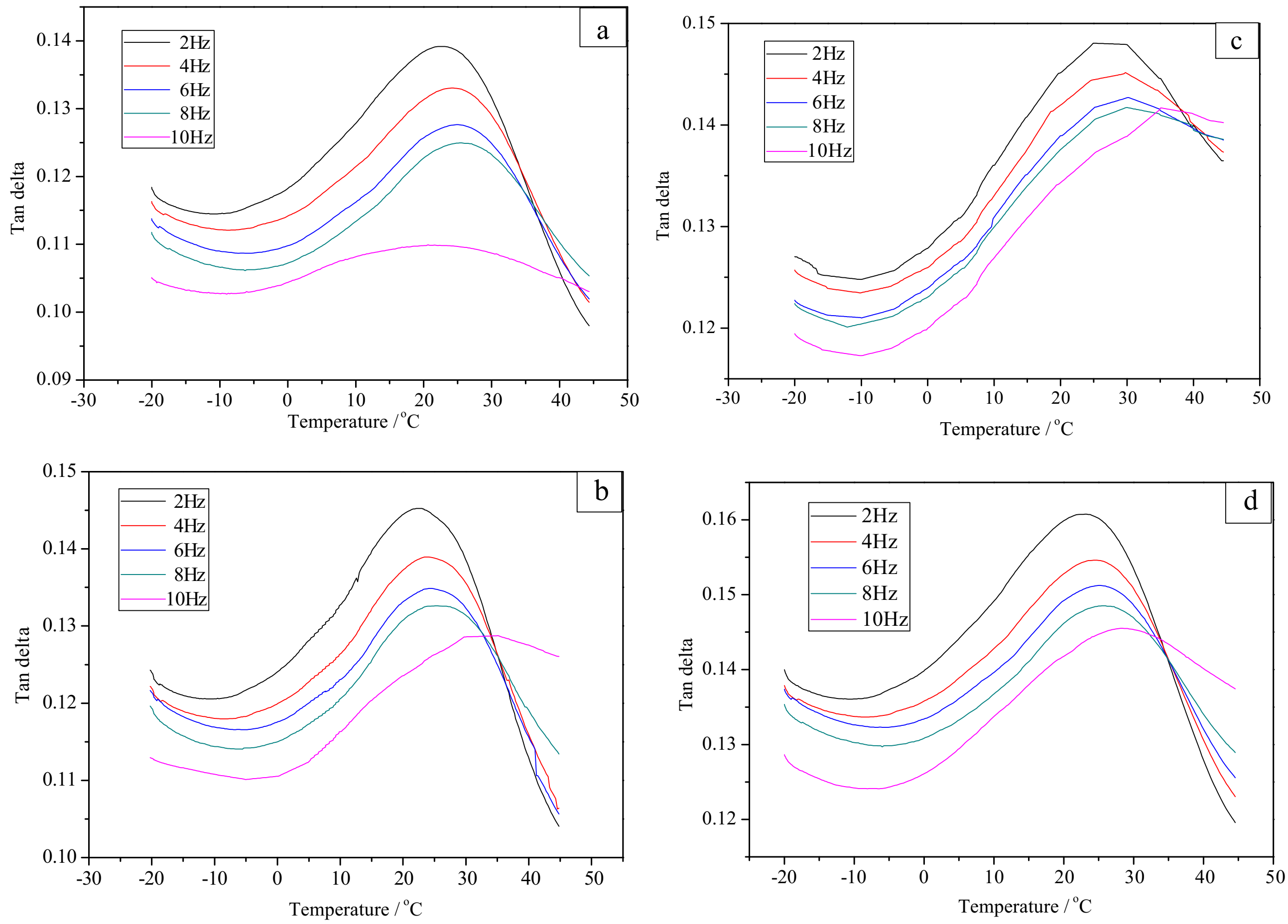

Fig. 8. Loss factor changes with temperature at different frequencies for the mortars with different *a*/*c* ratios: (a) 0.17, (b) 0.20, (c)0.23 and (d) 0.26.

3.2.3. Loss factors of the mortars at different temperature and a/c ratios

Fig. 9 shows the loss factor changes with temperature at different frequencies for the mortars with different *a*/*c* ratios. It is obvious that the highest value of loss factor for the mortar with 0.26 *a*/*c* ratio moves to the right about 6.6 °C that of the mortar with 0.17 *a*/*c* ratio at the loading frequency of 10 Hz. The loss factor of the mortar increases with the increase of temperature. The higher the temperature is, the softer the asphalt is; so the dissipation capacity of the mortar is stronger. Because of the temperature performance of the asphalt material, the viscoelasticity of the mortar is improved, the energy dissipation of the mortar is increased; and the damping performance of the mortars is improved at the same time.

According to Eq. (3), the E' is the real part of the complex modulus; and it is also referred to as the storage modulus. It can be expressed as Eq. (4)

$$E' = E\cos\theta \tag{4}$$

The E'' is the imaginary part of the complex modulus. It determines energy dissipation transformed into a thermal when the damping material is subjected by compression deformation. So it is also referred to as the loss modulus. It is shown as Eq. (5).

$$E'' = E\sin\theta = \eta E' \tag{5}$$

As shown in Figs. 9 and 10, it's obvious that the addition of asphalt emulsion can improve the loss modulus E'' of cement asphalt emulsion mortars. The higher the content of asphalt emulsion, the higher the loss modulus E'', as well as the higher the loss factor η of the mortars. When the temperature increases, the loss modulus of the control group is almost unaffected, but the loss modulus of the four groups of cement asphalt emulsion mortars decreases. And the higher the content of asphalt emulsion, the higher the decrease of loss modulus of cement asphalt emulsion mortars.

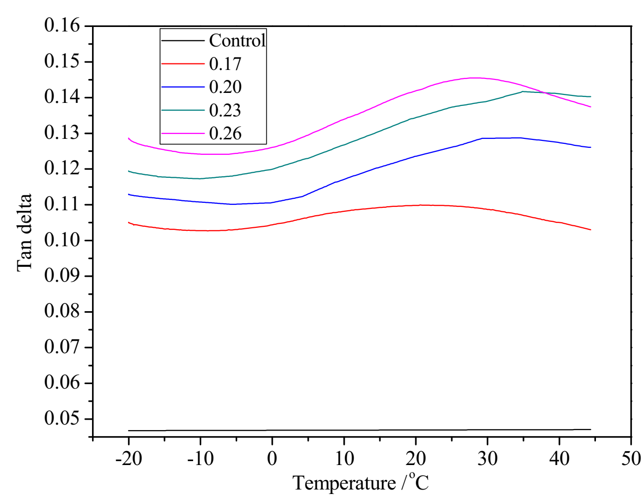

Fig. 9. Loss factor changes of the mortars with different *a*/*c* ratios at different temperature.

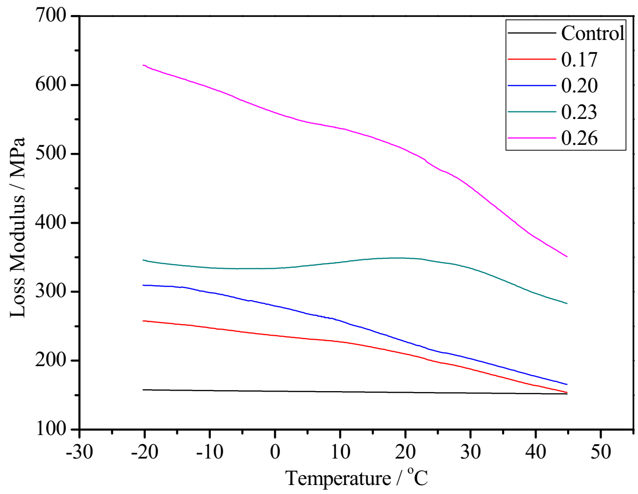

Fig. 10. Loss modulus changes of the mortars with different a/c ratios at different temperature.

3.3. ESEM observations

Fig. 11 shows the ESEM micrographs of the mortars with different a/c ratios. It's obvious that more and more asphalt is encircled in the surface of cement particles with the increase of the content of emulsified asphalt. The effect of hindering cement hydration can be aggravated with the increase of asphalt content [24–25]; and the rigidity of the mortar can decrease. At the same time, asphalt can contact with surface of cementitious materials more fully with the increase of the asphalt content in cement asphalt emulsion mortar; and the pores in the mortars can be filled with more asphalt as shown Fig. 11. Therefore, the increase of asphalt content improves the viscoelasticity of the mortars.

Fig. 11 shows that it is obvious that the hydration products in cement asphalt emulsion mortar are obviously decreased with the increase of a/c ratio. In Fig. 11(a) and (b), it can seen that floc wraps on the surface of cement hydration products CH crystals and C-S-H gels, which is the free asphalt after emulsified demulsification. In Fig. 11(c), a clear network structure can be seen; granular particles, C-S-H gels and free asphalt are interwoven with a strong space. It's more obvious that there is large white smooth free asphalt in Fig. 11(d). The free asphalt flows into the pores between the hydration of cement with sand and fills the pores. The visible free asphalt in cement asphalt emulsion mortar increases obviously with the increase of asphalt emulsion content. The presence of the reticular asphalt film between the cement hydrates can block the hydration of the cement, which can result in a decrease in the mechanical strength of the mortars. However, the rigidity of cement asphalt emulsion mortar is improved because of the viscoelasticity performance of the asphalt.

4. Conclusions and summary

This experimental study has focused on the effects of a/c ratios in enhancing the damping properties of the cement asphalt emulsion mortars. On the basis of the experimental tests and the theoretical analyses, the following conclusions can be drawn:

1) With the increase of a/c ratios, compressive strength and flexural strength of cement asphalt emulsion mortars decrease. However, the higher a/c ratio can improve the ability to resist the deformation and enhance the plasticity of the mortars. Asphalt attached to surface of cement hydrated

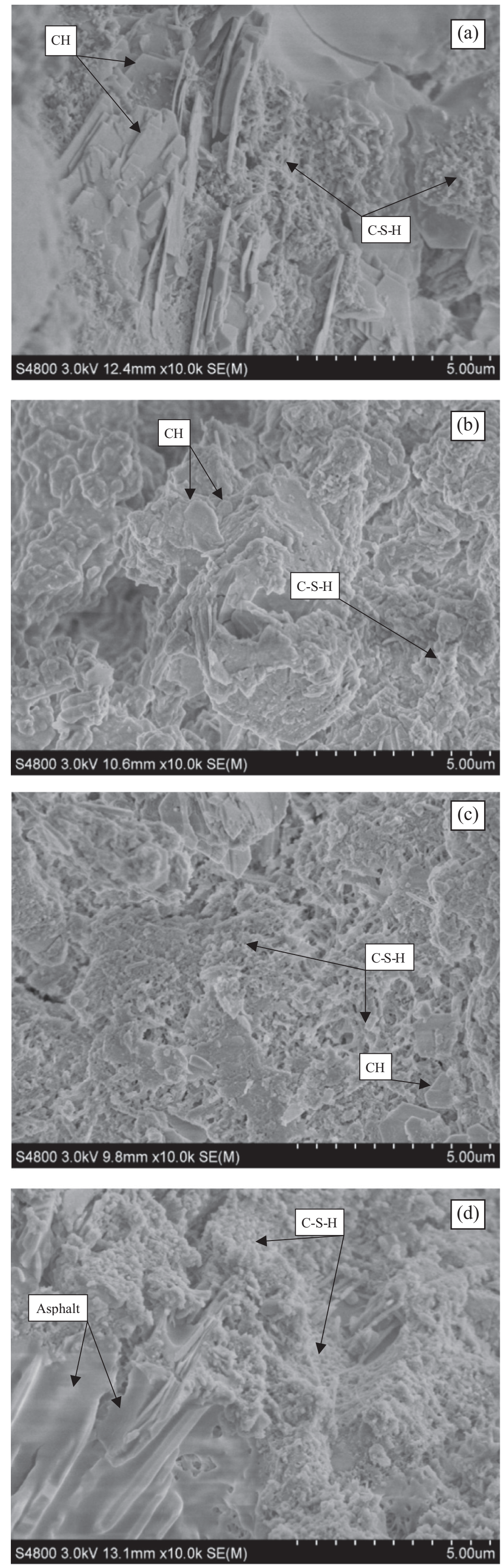

Fig. 11. ESEM micrographs of the mortars with different a/c ratios: (a) 0.17, (b) 0.20, (c) 0.23 and (d) 0.26.

products increases significantly with the increase of a/c ratio, which directly influences mechanical properties of the mortars.

2) The addition of asphalt emulsion can significantly improve the damping performance of the cement asphalt emulsion mortar. For, the cement asphalt emulsion mortars with 0.17 a/c ratio, the rigidity of the mortar is dominant and the viscoelasticity of the mortar is very poor. The higher the asphalt emulsion content is, the greater the loss factor of the cement asphalt emulsion mortar is. The energy dissipation capacity of the mortar can be stronger.
3) The damping performance of cement asphalt emulsion mortars is influenced by the loading frequency. The loss factor of cement asphalt emulsion mortar exists a higher increase at low loading frequencies and a lower increase at high loading frequencies.
4) At the same loading frequency, the loss factor of cement asphalt emulsion mortar increases and the loss modulus of the mortar decreases with the increase of temperature. However, the loss factor has a small change at low temperature and a tremendous change at high temperature.
5) In a word, damping performance and strength are influence greatly by contents of cement and asphalt emulsion in accordance with the analysis of the evaluation and experimental results. The less cement content or higher asphalt emulsion content, the higher damping performance; on the contrary, it is opposite. It needs to coordinate the damping performance and strength for different applications of cement asphalt emulsion mortar. The demands of damping performance and strength are determined by the engineering characters, such as railway structure, loads, and so on. For example, more asphalt emulsion is needed in type I cement asphalt emulsion mortars because the railway structure needs more damping performance; while more cement is added in type II cement asphalt emulsion mortars because the railway structure needs more strength compared to the damping performance.

Conflict of interest

The authors declare that they have no conflict of interest.

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