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Research Article

Experimental Research on Compression Properties of Cement Asphalt Mortar due to Drying and Wetting Cycle

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Uniaxial compression test of cement asphalt (CA) mortar specimens, due to drying and wetting cycle of 0, 2, 4 and 8 times, is carried out by using the electronic universal test machine, with the strain rate ranging from $1 \times 10^{-5}\,s^{-1}$ to $1 \times 10^{-2}\,s^{-1}$. The effects of strain rate and drying and wetting cycle time on the compressive strength, elasticity modulus, and stress-strain full curve are investigated. Experimental results show that the strain-stress full curve of CA mortar is affected obviously by strain rate and drying and wetting cycle time. The compressive strength and elasticity modulus increase with the strain rate under the same drying and wetting cycle time. The compressive strength and elasticity modulus decrease with the increase of drying and wetting cycle time in the same strain rate. The lower the strain rate is, the greater the compressive strength and elasticity modulus of CA mortar decrease. When the strain rate is $1 \times 10^{-5}\,s^{-1}$ and drying and wetting cycle time is 8, the largest reduction of average compressive strength of CA mortar is 40.48%, and the largest reduction of elasticity modulus of CA mortar is 35.51%, and the influence of drying and wetting cycle on the compressive strength of CA mortar is greater than its influence on the elasticity modulus.

1. Introduction

Slab ballastless track is a track structure, which is widely used in high speed railway (HSR). The cement emulsified asphalt mortar (CA mortar) layer as a filling layer between track slab and concrete supporting layer functions in support, load transfer, adjustment, reduction, and isolate vibration [1–5]. The long-term service performance of CA mortar is very important in the regularity and durability of track and the safety and comfort of the vehicle driving [6, 7].

As the buffer, damping structure layer of slab ballastless track, CA mortar is mainly under the vertical load and in dynamic loading process [8, 9], so the influence of loading rate on the mechanical properties of CA mortar was researched in paper [10–13]. Wang et al. [10] explored the variation in compressive strength of CA mortar under different loading rates. Kong et al. [11] tested the compressive stress-strain of two CAMs at different displacement rates ranging from 0.3 mm/min to 30 mm/min. And the correlation between peak strength or elastic modulus and loading rates was acquired. Yongliang et al. [12] tested two typical CAMs at varied deformation rates over a range of 0.3 to 30 mm/min at room temperature, and the correlation between the mechanical properties and temperature or loading rates was acquired. Xie et al. [13] studied the single-axis compressive characteristic of CRTS I type slab tracks CA mortar under different strain rates. CA mortar is vulnerable in natural environmental conditions chronically under its service process. The rain and sun cycles will have a negative impact on the mechanical properties of CA mortar inevitably, but the variation law on mechanical properties of CA mortar under the drying and wetting cycle has not been reported in China or abroad. In this paper, the writer studied the deterioration laws of mechanical properties of CA mortar, using specimen of CA mortar made in laboratory on the basis of the drying and wetting cycle experiment, which can provide an experimental basis for the deterioration mechanism of CA mortar.

2. Experimental

2.1. Raw Materials. Cement emulsified asphalt mortar special dry ingredients are mainly mixed with cement, sand,

Table 1: Properties of emulsified asphalts.

Number	Item		Unit	Requesting	Value
1	Engler viscosity (25°C)			5~15	8.0
2	Ratioof screen residue (1.18 mm)		%	<0.1	0
3	Storage stability (1 d, 25°C)		%	<1.0	0.3
4	Storage stability (5 d, 25°C)		%	<5.0	3.2
5	Residue of mixing with cement		%	<1.0	0.3
6	Evaporated residue	Needle penetration (25°C, 100 g)	0.1 mm	60~120	78.5
7		Solubility (trichloroethylene)	%	>97	98.0
8		Ductility (5°C)	cm	⩾20	26.5
9		Ductility (15°C)	cm	⩾50	61.2

(a) Standard specimen of CA mortar

(b) CA mortar specimens immersed in water

Figure 1: CA mortar specimens.

and other additives. Its basic mixture ratio is cement : sand : expanders = 1 : 2 : 0.1. Pure Portland cement with a strength grade of 42.5, complying with the Chinese National Standard GB175-1999, was used. The 24 h volume expansion rate of this cement emulsified asphalt mortar special dry ingredients is 2.1%, whose 7 d line expansion rate is 0.1% and the 1-day compressive strength is 6.89 MPa.

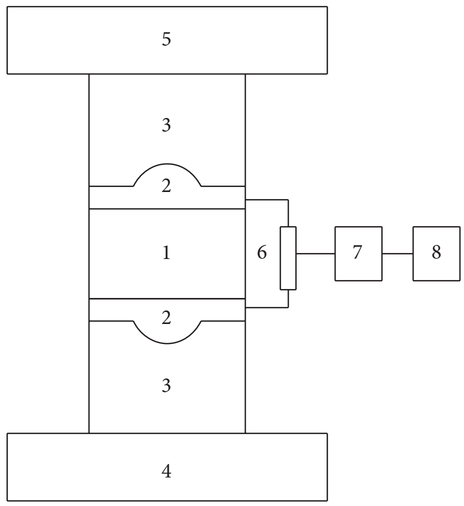
The asphalt emulsion is the special emulsified asphalt of CA mortar on CRTS I type slab ballastless track, whose solid mass fraction is 62.1%. And the viscosity, penetration, and ductility of asphalt emulsion can meet the requirements of the temporary technology criterion of cement and emulsified asphalt mortar in CRTS (China railway track system) I type slab track of passenger dedicated railway, whose main properties are listed in Table 1.

The J-funnel flow time of fresh CA mortar is 24 s, and the resolution is 0.2%. The mix proportion of CA mortar is m(dry ingredients) : m(asphalt) : m(water) = 1100 : 515 : 50. Mixing water is the tap water.

2.2. Sample Preparation. According to the given mixture of CA mortar, put the emulsified asphalt and water into the pot and stir slowly, and add the dry ingredients into the spot slowly in the slowly stir condition. After the dry ingredients were added, stir rapidly for 3 min and then stir for 1 min. The fluidity, apparent density, gas content, and other properties of fresh CA mortar were measured according to the method in [10]. The fluidity of CA mortar was 24 s. The apparent density was 1610 $\mathrm{kg{\cdot}m^{-3}}$ and the gas content was 8.2%. Then fresh CA mortar was placed into cylindrical plastics moulds with size Φ 50 mm × 50 mm, forming 90 specimens. After being cured in the constant temperature (23 ± 2)°C and constant humidity (65 ± 5)% for 24 hours, the samples were removed from the moulds, transferred into the standard room, and cured for 120 days, and then we did the drying and wetting cycle experiment and compression test.

2.3. Testing Method. In order to simulate the condition of CA mortar layer under drying and wetting cycle, CA mortar specimens were immersed in water for 7 days and then put them in outdoor for natural withering 7 days. The environment temperature was kept at 20°C, and the drying and wetting cycle times were 0, 2, 4, and 8. And then, at the regulation age, the mechanical property of CA mortar specimens was tested. The CA mortar specimens and the specimens which were immersed in water were given in Figure 1.

The mechanical property test of CA mortar, uniaxial compressive test of CA mortar specimens in different immersion time, was carried out by using the universal electronic test machine (Figure 2) according to the method in paper [6], keeping the environment temperature at 20°C when testing. Considering the loading ability of the experimental system, loading rates of 0.03 mm/min, 0.3 mm/min, 3 mm/min, and 30 mm/min were set for testing the CA mortar specimens. Strain rates were $1 \times 10^{-5}\,\mathrm{s^{-1}}$, $1 \times 10^{-4}\,\mathrm{s^{-1}}$, $1 \times 10^{-3}\,\mathrm{s^{-1}}$, and $1 \times 10^{-2}\,\mathrm{s^{-1}}$, which were obtained according to the size of CA mortar specimens, taking $1 \times 10^{-5}\,\mathrm{s^{-1}}$ as a quasistatic



(1) Test specimen
(2) The hinge of loading head
(3) Loading member bar
(4) Load transducer
(5) Servosystem
(6) Displacement sensor
(7) Signal conversion equipment
(8) Data collection system

Figure 2: The schematic of universal testing machine in the loading direction.

strain rate. Two loading surfaces were coated with French chalk to reduce the surface restraint effect and three samples were used for each test as duplication. If the test results are discrete, the number of specimens should be increased in order to ensure the validity of test data. Specimens should be preloaded three times with loading rate of 0.5 mm/min and strength of 0.05 MPa before the formal loading in order to prevent the error because of the surface unevenness of CA mortar samples.

3. Results and Discussion

3.1. Stress-Strain Curve of CA Mortar. The mechanical property of CA mortar was fully reflected by the stress-strain full curve of CA mortar. The stress-strain full curves of CA mortar of CRTS I slab ballastless track are shown in Figure 3. Figure 3(a) shows the stress-strain full curves of CA mortar under different strain rates, without drying and wetting cycle. As shown in Figure 3(a), the stress-strain curves of CA mortar change obviously under different strain rates, and the ultimate compressive strength of CA mortar increases with the strain rate. Figure 3(b) shows the stress-strain full curves of CA mortar under different drying and wetting cycle times when the strain rate is $1 \times 10^{-4}\ s^{-1}$. As shown in Figure 3(b), the ultimate compressive strength of CA mortar decreases with the increase of drying and wetting cycle time. The strength of CA mortar decreases slowly when the strength of CA mortar reaches the peak strength. The existence of asphalt improves the fracture toughness of CA mortar, and the CA mortar still has enough bearing capacity when the strain reaches 10%, which indicates that the CA mortar has good toughness and ductility.

Table 2: Compressive strengths of CA mortar under different drying and wetting cycle times.

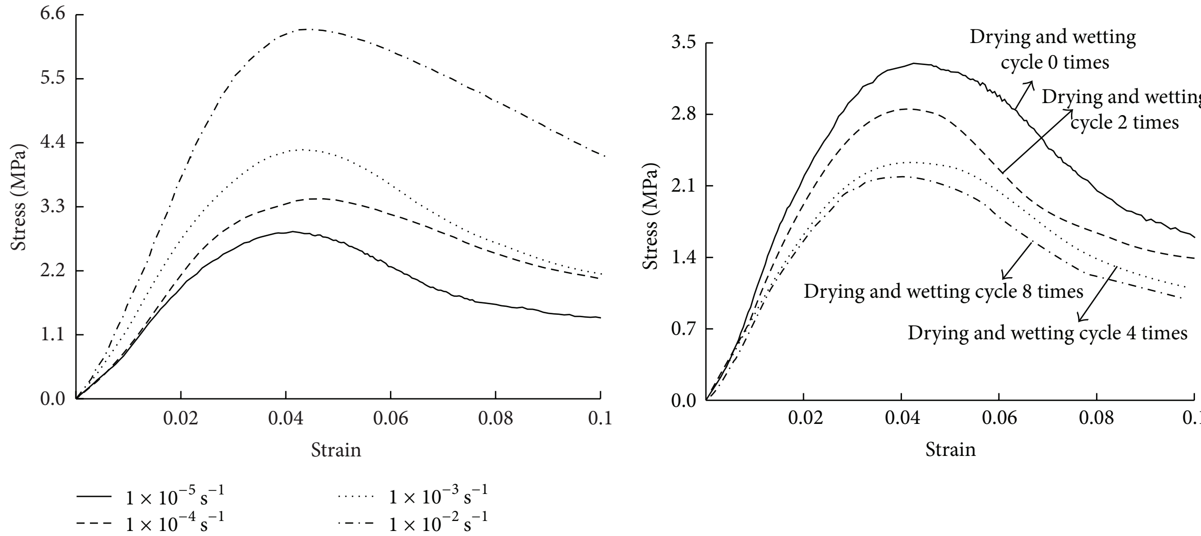
Strain rates/s^{-1}	Test	Compressive strength/MPa			
		0 times	2 times	4 times	8 times
1×10^{-5}	1	3.301	2.872	2.051	1.915
	2	3.277	2.882	2.058	2.017
	3	3.367	2.981	2.129	1.987
	Average	**3.315**	**2.912**	**2.079**	**1.973**
1×10^{-4}	1	3.858	3.594	2.871	2.456
	2	3.781	3.448	2.764	2.537
	3	3.954	3.501	2.765	2.412
	Average	**3.864**	**3.514**	**2.800**	**2.468**
1×10^{-3}	1	5.283	4.285	3.684	3.299
	2	5.232	4.221	3.739	3.403
	3	5.192	4.084	3.619	3.255
	Average	**5.235**	**4.196**	**3.680**	**3.319**
1×10^{-2}	1	7.121	6.349	5.040	4.622
	2	7.184	6.261	4.903	4.508
	3	7.102	6.183	4.917	4.587
	Average	**7.135**	**6.264**	**4.953**	**4.572**

3.2. Compressive Strength of CA Mortar. The uniaxial compressive strength of CA mortar under different drying and wetting cycle times and strain rates are shown in Table 2.

As shown in Table 2, the ultimate compressive strength increases with the strain rate under the same drying and wetting cycle time. After drying and wetting cycle for 0, 2,4, and 8 times, the average strength of CA mortar in the strain rates of $1 \times 10^{-4}\ s^{-1}$, $1 \times 10^{-3}\ s^{-1}$, and $1 \times 10^{-2}\ s^{-1}$ increases by 16.56%, 20.67%, 34.68%, and 25.09%, 57.92%, 44.09%, 77.01%, and 68.22%, and 115.23%, 115.11%, 138.24%, and 131.72% comparing with that in the strain rate of $1 \times 10^{-5}\ s^{-1}$. The strength of CA mortar comes from the hydration of cement and demulsification of asphalt emulsion, and the skeleton structure of CA mortar is formed by the asphalt being coated with hydration product of cement and sand [14]. The strength of CA mortar is provided by the connection between cement hydration products and asphalt or connection between sand and asphalt. Damage of CA mortar is mainly caused by the internal crack of its skeleton. With the increase of strain rate, the microcrack of CA mortar could not extend timely, and the lateral inertia confinement effect of asphalt's network structure will prevent the development of microcrack, which results in the compressive strength improvement of CA mortar.

Influences of strain rate on the compressive strength of CA mortar under different drying and wetting cycle times are shown in Figure 4.

As shown in Table 2 and Figure 4, the ultimate compressive strength of CA mortar decreases with the increase of drying and wetting cycle time under the same strain rate. When the strain rates are $1 \times 10^{-5}\ s^{-1}$, $1 \times 10^{-4}\ s^{-1}$, $1 \times 10^{-3}\ s^{-1}$, and $1 \times 10^{-2}\ s^{-1}$, the drying and wetting cycle times are 2, 4, and 8, and the average compressive strength of CA mortar decreases by 12.15%, 9.06%, 19.84%, and 12.21%,



(a) Different strain rates

(b) Strain rate is $1 \times 10^{-4}\ s^{-1}$

Figure 3: Stress-strain full curves of CA mortar.

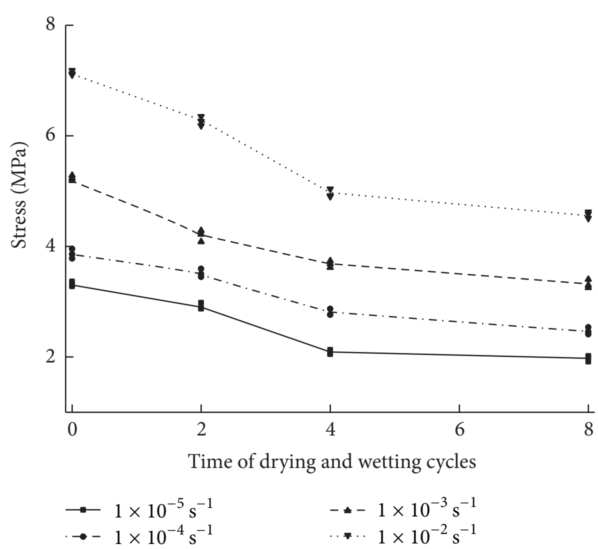


Figure 4: Compressive strength of CA mortar at different strain rates and drying and wetting cycle times.

37.28%, 27.53%, 29.70%, and 30.58%, and 40.48%, 36.12%, 36.59%, and 35.92% compared with that without drying and wetting cycle. The stress generated by dry shrinkage and wet expansion deformation of CA mortar will damage the CA mortar with the developing of drying and wetting. The stress concentration zoon, which is formatted in the weak interfaces between network of asphalt and cement hydration products and between network structure and sand, results in micropore and cracks. The internal damage of CA mortar accumulates continually, and the strength of CA mortar reduces gradually. When the microcracks extend to a regular degree, the stress generated by dry shrinkage and wet expansion will decrease continuously. In the macroscopic level, the decrease of compressive strength of CA mortar trends to stability.

3.3. Relationship between Elasticity Modulus and Cycle Time. The elasticity modulus of materials reflects the recovery capacity of deformation; the higher the elasticity modulus, the stronger the recovery capacity of deformation. Use the secant modulus of compressive strength of 0~1/3 as the elastic modulus of CA mortar [13], which is the following formula:

$$E_d = \frac{(\sigma_{1/3} - \sigma_0)}{(\varepsilon_{1/3} - \varepsilon_0)}, \quad (1)$$

in which E_d is the elasticity modulus of CA mortar and $\sigma_{1/3}$ is the 1/3 of ultimate compressive strength. σ_0 is the initial stress. In this experiment, σ_0 is 0. $\varepsilon_{1/3}$ is the strain corresponding to $\sigma_{1/3}$. ε_0 is the initial strain value, which is 0. Through the analysis of stress-strain curve, the elasticity moduli of CA mortar at different drying and wetting cycle times are shown in Table 3.

Table 3 demonstrates that the elasticity modulus of CA mortar increases with the strain rate under the same drying and wetting cycle time. After drying and wetting cycle for 0, 2, 4, and 8 times, the elasticity modulus of CA mortar in the strain rates of $1 \times 10^{-4}\ s^{-1}$, $1 \times 10^{-3}\ s^{-1}$, and $1 \times 10^{-2}\ s^{-1}$ increases by 10.48%, 7.28%, 14.77%, and 16.43%, 39.08%, 34.30%, 51.95%, and 47.88%, and 87.87%, 88.94%, 102.76%, and 102.02% compared with that in the strain rate of $1 \times 10^{-5}\ s^{-1}$. The elasticity modulus of CA mortar reflects the recovery capacity of deformation, so the sensibility of strain rate on the elasticity modulus of CA mortar can improve the stability of train driving.

Influences of strain rate on the average elastic modulus of CA mortar under different drying and wetting cycle times are shown in Figure 5.

Table 3: Elasticity modulus of CA mortar under different drying and wetting cycle times.

Strain rates/s^{-1}	Test	Elastic modulus E/MPa 0 times	2 times	4 times	8 times
1×10^{-5}	1	88.400	72.509	65.867	56.372
	2	84.466	76.698	60.604	55.212
	3	79.382	84.585	54.641	51.005
	Average	**84.082**	**77.931**	**60.370**	**54.196**
1×10^{-4}	1	94.824	87.467	75.179	62.379
	2	88.195	85.362	61.631	59.477
	3	95.666	77.999	71.060	67.446
	Average	**92.895**	**83.609**	**69.290**	**63.101**
1×10^{-3}	1	124.793	109.343	90.576	80.792
	2	110.982	100.494	89.461	77.084
	3	115.053	104.158	95.169	82.562
	Average	**116.942**	**104.664**	**91.736**	**80.146**
1×10^{-2}	1	150.201	142.525	115.953	107.252
	2	162.436	152.803	123.504	107.602
	3	161.260	146.402	127.761	113.613
	Average	**157.966**	**147.243**	**122.406**	**109.489**

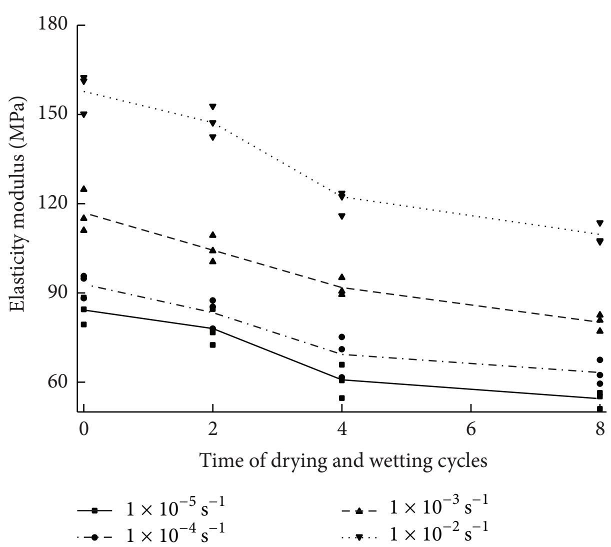


Figure 5: Elastic modulus of CA mortar.

As shown in Table 3 and Figure 5, elasticity modulus of CA mortar decreases with the increase of drying and wetting cycle time under the same strain rate. When the strain rates are $1 \times 10^{-5}\,s^{-1}$, $1 \times 10^{-4}\,s^{-1}$, $1 \times 10^{-3}\,s^{-1}$, and $1 \times 10^{-2}\,s^{-1}$, the drying and wetting cycle times are 2, 4, and 8; the average elastic modulus of CA mortar decreases by 7.31%, 9.99%, 10.49%, and 6.79%, 28.20%, 25.41%, 21.55%, and 22.51%, and 35.51%, 32.07%, 31.46%, and 30.69% comparing with that without drying and wetting cycle. With the continuation of drying and wetting cycle, the internal structure of CA mortar will be damaged, the recovery capacity of deformation will be weakened, and the elasticity modulus of CA mortar decreases gradually. The reason is similar to the change of CA mortar's compressive strength. The attenuation rate of elasticity modulus of CA mortar decreases slowly.

4. Conclusions

The stress-strain relationship of CA mortar under different strain rates and drying and wetting cycle times has been got through the uniaxial compression experiment, and the change rule of related mechanics index has also been analyzed. The following conclusions can be drawn.

(1) The mechanical property of CA mortar is influenced obviously by strain rates and drying and wetting cycle times.

(2) Because the stress generated by dry shrinkage and wet expansion deformation of CA mortar will damage the CA mortar, the compressive strength and elasticity modulus decrease with the increase of drying and wetting cycle times in the same strain rate. When the strain rate is $1 \times 10^{-5}\,s^{-1}$ and the drying and wetting cycle time is 8, the largest reduction of average compressive strength of CA mortar is 40.48%, and the largest reduction of elasticity modulus of CA mortar is 35.51%.

(3) Under the same drying and wetting cycle time, since microcracks inside the CA mortar can not develop in time, the ultimate compressive strength and elastic modulus will increase with the strain rate. The maximum increase of compressive strength is 138.24%, and the largest increase of elasticity modulus is 102.76%.

(4) The influence of drying and wetting cycle on the compressive strength of CA mortar is greater than its impact on the elasticity modulus.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

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