Advanced Engineering Forum
ISSN: 2234-991X, Vol. 5, pp 243-246
doi:10.4028/www.scientific.net/AEF.5.243

Online: 2012-07-26

Dynamic Characteristics of Rubber Powder Modified Cement Asphalt Mortar

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Keywords: cement asphalt mortar (CA), rubber powder, natural frequency, damping

Abstract. Cement asphalt mortar (CA) is mainly applied in track system of high-speed railways for vibration attenuation. The impact on dynamics performance of CA with the admixture of rubber powder was studied. The beam specimen made of CA was manufactured for analyzing its vibration frequency and damping characteristics by free attenuation vibration tests. Results showed that there was no big change for fundamental frequency after admixture of rubber powder. However, high order frequency and structural damping increased with the increase of admixture amount. Damping ratio of CA was increased by admixing rubber powder, which can be better for energy absorption and vibration attenuation.

Introduction

Cement asphalt mortar (CA) is the key engineering material in the slab track system of high-speed railways. It is a kind of inorganicorganic composite material consisting of Portland cement, asphalt emulsion, water, fine aggregates, and other admixtures. It is a semi-rigid composite material of which, the matrix is formed by cement hydration and emulsified asphalt breaking. CA is injected in between the track slab and concrete roadbed (Fig.1), and it is an essential supporting and force transmission component, which can provide adequate rigidity and toughness for the track[1,2].

During the last decade, research has mainly focused on various aspects of CA, such as formulation, construction technology, mechanical properties and durability [3-7].Vibration attenuation effect on CA has been less involved in recent research. High-speed trains have a great impact on sub-rail foundation under operation. The existence of CA can consume the energy produced during impact procedure, making vibration and impact effect be reduced to ensure train operation stable and comfortable. CA can also decrease force impact on sub-rail foundation and reduce maintenance and repair costs to keep the whole line in an outstanding service performance for a long time. Thus vibration attenuation effect is considered as one of the most important functions of CA. The vibration attenuation function was improved by admixing rubber powder into CA and the CA beam specimen was applied to evaluate the vibration frequency and damping characteristics by free attenuation vibration tests. The impact on dynamics performance of CA with the admixture of rubber powder was analyzed and estimated.

Materials and experimental investigation

Materials. Cement(C): were ordinary portland cements P.I 42.5, The properties of the three cements were listed in Table 1. Asphalt emulsion(A): anion slow-breaking emulsion asphalt. The properties of the three asphalt emulsion were listed in Table 2. Sand(S) is graded sand blended by two single size sand of 0.15~0.3mm(S1), 0.3~0.6mm(S2). Water(W) was tap water. Water reducing agent(WT) is polycarboxylic type superplasticizer. Defoamer(D) is tributyl phosphate. Fineness of rubber powder (RP) can be divided into three groups as 30~50 mesh, 50~100 mesh and 100~200 mesh.

Table 1 Physical properties of cements

Surface density (g/cm^3)	Setting sime(min)		Compressive strength(MPa)		
	Initial set	Final set	3d	7d	28d
3.05	135	180	15	21.5	46.9

Table 2 Properties of anion asphalt emulsion

Density (g/cm^3)	Storage stability 5d (%)	Sieve test (%)	Penetration (25)	Solid content (%)
1.01	0.1	0.02	79	60

Preparation of CA. Ratio of raw materials for CA takes cement as benchmark and other materials are provided according to mass ratio of cement. Rubber powder was added into raw materials instead of the same mass asphalt to make sure the total mass of raw materials is a constant. Dosage of sand was reduced to keep the volume of raw materials as a constant. (mix proportions of cement mortar was listed in Table 3). To simulate the mixing sequence in the field, raw materials were weighed and homogenously mixed according to the mixing sequence in Fig.2. Fresh mortar was then cast into 403403160 mm^3 molds. Specimens were demoulded after 1 day and cured at 60±5% relative humility and 20±2^{o}C temperature until the age of 28 days.

Table 3 Mix proportions of CA

C	A+RP	S	W	RP	WT	D	AI
1	0.22	1.6	0.4	0.03,0.06,0.09	0.012	0.001	0.00004

[a]All mass ratios are relative to cement. Ratio for total mass of asphalt and rubber to cement is 0.22, rubber instead of asphalt with the same mass.
[b] Water in the asphalt emulsion is counted into the calculation of W/C.

Experimental methods

Natural frequency and damping ratio of specimen were obtained by free attenuation vibration tests. One end of the beam was fixed as boundary condition. Excitation was applied using modal force hammer. Structural responses were measured by acceleration transducers. Data were collected and analyzed by model recognition software to obtain natural frequency and damping ratio of specimen.

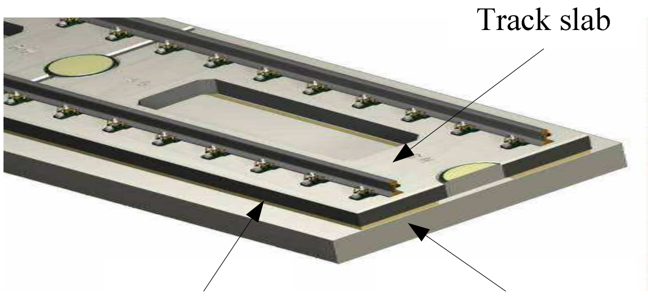

Fig.1 Structure of slab track

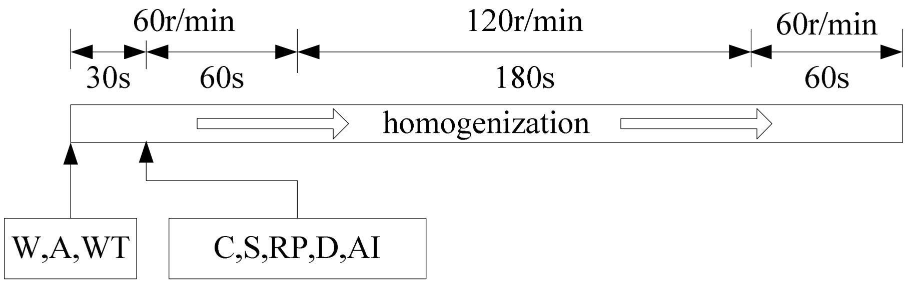

Fig.2 Mixing sequence of CA

Results and discussions

Effect of rubber powder on natural frequency of CA. Figures 3 to 5 show effects of different rubber powder quantities on structural vibration frequency. Quantities of rubber powder are 0, 0.03, 0.06 and 0.09 (mass ratio to cement), respectively. Effects due to different degrees of rubber powder particles (30-50 mesh, 50-100 mesh and 100-200 mesh) were considered. Experimental results indicate that the first three order natural frequencies without rubber powder are 152Hz, 197Hz and 225Hz. First order frequency varies from148 Hz to 156 Hz after admixture of rubber powder. Maximal change is only 3.9% in first order frequency which indicates that rubber powder in different thick degrees have little effect on first order frequency. Quantity of rubber powder has big effects on second and third natural frequencies of structure with 8.6% increase in second order frequency and 33.3% increase in third order frequency. With the increase of rubber powder amount, second and third order frequencies generally increase and, the thicker the rubber particle, the more effect on frequency.

Effect of rubber powder on CA damping. Figure 6 is a curve showing effect of rubber powder amount on structure damping. Structural damping increases with the increase of rubber powder amount. The damping is 2.75% without rubber powder and increases to 3.5% (27.3% change) when rubber powder amount is 0.09. The thinner the rubber powder, the more effect on structure damping. Thus introducing thinner rubber powder can effectively increase structure damping to enhance energy absorption and vibration attenuation functions of CA.

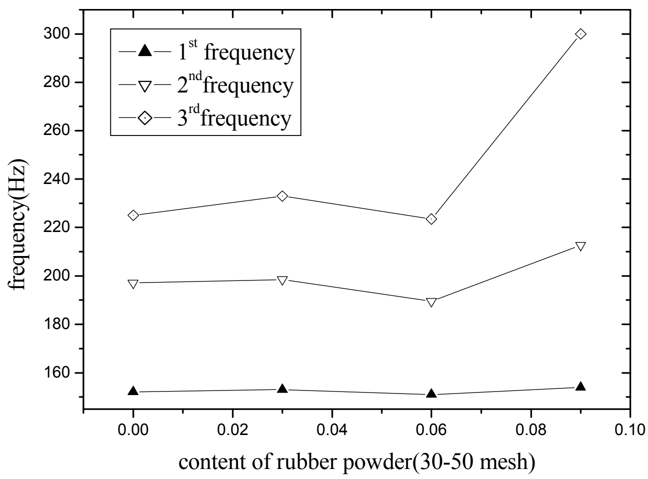

Fig.3 Effect of rubber powder onfrequencies(30-50 mesh)

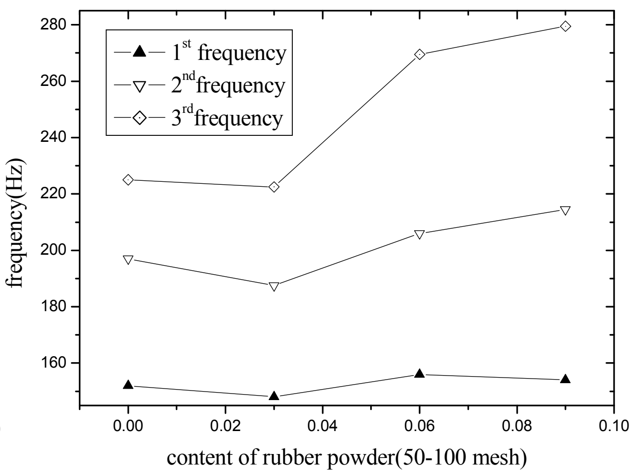

Fig.4 Effect of rubber powder on frequencies (50-100 mesh)

Rubber is a kind of high elastic damping material. Elastic deformation performance of CA mortar is increased after admixture of rubber powder to absorb more energy and increase structure damping, which has little effect on structural fundamental frequency simultaneously.

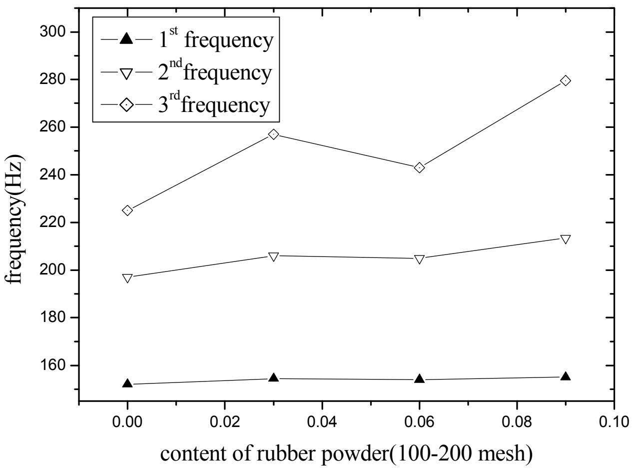

Fig.5 Effect of rubber powder on frequencies (100-200 mesh)

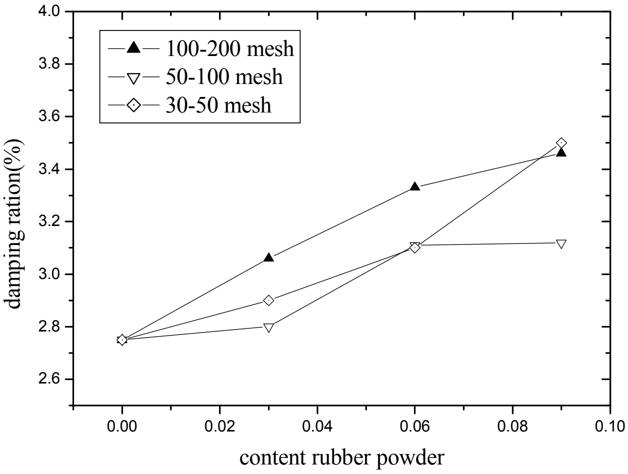

Fig.6 Effect of rubber powder on damping (50-100 mesh)

Conclusions

Natural frequency and damping characteristics of cantilever beam specimen made by CA with different admixtures of rubber powder were analyzed using free attenuation vibration tests. Experimental results indicated that there was no big change in fundamental frequency after admixture of rubber powder in CA, but great effects existed on high order frequencies. Damping ratio of beam specimen increased with the increase of rubber powder amount. Rubber powder can improve damping performance of CA for better usage in energy absorption and vibration attenuation.

Acknowledgements

Research support by the National Natural Science Foundation of China(NO.51078114) and Research Fund for the Doctoral Program of Higher Education of China(NO.20102302120058) is gratefully acknowledged.

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