A Novel Method for Improving Segregation Resistance of Cement Asphalt Mortar

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\textbf{ABSTRACT:} Cement asphalt mortar (CA mortar) is the key component in the structure of Shinkansen slab track and serves as the elastic shock-absorber. CA mortar is a fluid mixture suitable for placing in structures without vibration. CA mortar development must ensure a good balance between fluidity and stability. Hydrophobically associating water-soluble polymers not only have the unique advantage of segregation resistance but also good properties of fluidity. The fluidity and segregation tests show that by adding hydrophobic associative polymer the degree of segregation of CA mortar is reduced without sacrificing the fluidity and workable time. The rheological test of CA mortar shows that the addition of hydrophobic associative polymer increases the viscosity and shear stress at low shear rates, but the viscosity and shear stress drops at high shear rates, imposing large resistances which alleviate the extent of segregation of CA mortar. The results show that hydrophobic associative polymer could be used successfully in producing CA mortar with reduced segregation potential.

\textbf{INTRODUCTION}

Ballastless slab track is one of the main track structures, which is widely applied in high speed railways in Japan, Germany, China and many other countries for a long time [1]. Cement and asphalt mortar (short for CA mortar) is an interlayer injected in the spaces between the track slab and the concrete roadbed, which is mainly applied in track system of high-speed railways for vibration attenuation. CA mortar mainly consists of cement, emulsified asphalt, sand, water, additives and several chemical admixtures, after the hydration cement and asphalt emulsion breaking interaction and then forming a composite material[2][3]. The hardening process of CA was the process that CA mortar changed from flow paste to hardening state, which included flow state, plastic state and hardening state [4].

During the past several years, some research work has been done on the relationship between the composition and properties of CA mortar. Cement setting process of CA mortar has been studied [5]. The hydration and hardening mechanism of cement asphalt binder was studied[6][7]. The presence of cement accelerated the breaking of asphalt emulsion in CA mortar[4]. Damping ratio of CA was increased by admixing rubber powder, which can be better for energy absorption and vibration attenuation [8]. A model to determine the mechanical properties of CA mortar in the field was proposed[9]. The destruction of CA mortar first occurred on the surface between slab track and CA mortar rather than that between concrete roadbed and CA mortar[10]. There are few publications...
focusing on its rheological behavior. The fly ash admixture was introduced to improve the separation rate and expansion of CA mortar[11].

During in situ construction, CA mortar is filled into a 6450×2550×(20-40)mm narrow space without any external pressure, so is characterized by ultrahigh fluidity, which necessitates good segregation resistance. The method for improving segregation resistance of CA mortar should be studied. The primary objective of this research was to provide a novel method for improving the segregation resistance of CA mortar without sacrificing the fluidity. The effect of various percentages of hydrophobically associating water-soluble polymer (HAWP) on CA mortar was investigated.

**MATERIALS AND METHODS**

**Materials.** Portland cement, P.II 52.5 from Nanjing Xiaoyetian, was used. The chemical compositions were shown in Table 1. Asphalt emulsion with solid content of 60% was used. Superplasticizer (SP) was supplied by Jiangsu Bote New Material Co., Ltd with 40% mass content. The fine aggregates (S) were river sand with maximum size of 1.18mm. Antifoaming agent (AFA) was Organic silicon. All the water (W) used was drinking water. HAWP was supplied by Shanghai Mingjie Chemical Co., Ltd.

In order to match with construction, the fluidity of standard mix proportion mortars were adjusted at the value of 110±2s. The standard mix proportion of CA mortar was listed in Table 2. In this study, four kinds of HAWP dosage were considered: 0‰, 1‰, 2‰, and 3‰ by weight of emulsified asphalt.

**Table 1. Chemical Compositions of Cement (w%).**

<table>
<thead>
<tr>
<th>CaO</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>SO₃</th>
<th>MgO</th>
<th>K₂O</th>
<th>LOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>65.09</td>
<td>20.53</td>
<td>4.50</td>
<td>3.47</td>
<td>2.19</td>
<td>0.96</td>
<td>0.62</td>
<td>1.74</td>
</tr>
</tbody>
</table>

**Table 2. Mixing proportions and materials type of CA mortar (kg/m³).**

<table>
<thead>
<tr>
<th>Asphalt</th>
<th>Cement</th>
<th>Water</th>
<th>Sand</th>
<th>Superplasticizer</th>
<th>Antifoaming agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>240</td>
<td>600</td>
<td>168</td>
<td>900</td>
<td>0.8</td>
<td>0.075</td>
</tr>
</tbody>
</table>

**Rheological test.** The rheological behavior of CA mortar was measured immediately using a Rheometer (R/S) equipped with coaxial cylinder measurement geometry in controlled shear rate mode at a constant temperature of 20°C. The measuring device was the CC25 spindle coaxial system. For all mortar samples, the rheological test program were shown in FIG. 1. Time, shear stress and shear rate were recorded and data was analyzed using Rheo2000 software for plotting of the flow curves. The up-curve was used to calculate various rheological properties.
Fluidity test. Fluidity test measured according to the tentative specification of cement asphalt mortar of CRTS II ballastless slab track. Fluidity test of CA mortar was indicated by pouring the grout into a funnel and measuring the flowing time until the grout drained away. Fluidity was defined as the interval time during which the fluidity of grout was between 80s and 120s.

Separation test. Pour the CA mortar into Φ50mm×50 mm cylindrical mould and scrape and cover the surface of testing mold with film, then move the mold into standard curing room where the temperature is 20±2°C and humidity is above 95%. After demould in 24 hours, keep the mold in the room for 7 days, then move the mold into the curing room where the temperature is 20±2°C, and humidity is 60±5%. When the mortar age is 28 curing days, cut it into halves and measure the density of each half. The separation rate is determined by the difference in density between top and bottom halves, which is given in Formula 1.

\[
\text{Separation rate} = \frac{\rho_1 - \rho_2}{\rho_1 + \rho_2}
\]

Where: \(\rho_1\) — density of bottom half, \(\rho_2\) — density of top half.

RESULTS AND DISCUSSION

Effect of HAWP on the rheological behavior of CA mortars. Fig.2 shown that the viscosity of CA mortar increased at low shear rates with the amount of HAWP added, after which viscosity would be dropped. At the shear rate of 3.41s-1, the viscosity of CA mortars containing of HAWP of 1‰, 2‰, and 3‰ were 2.176 Pa·s, 2.281 Pa·s, and 2.7635 Pa·s, respectively. However, the specimen without HAWP was 0.7468 Pa·s. When the shear rate was 40.68 s-1, the viscosity of 0‰, 1‰, 2‰ and 3‰ hydrophobic associative polymer were 0.3169 Pa·s, 0.2588 Pa·s, 0.2241 Pa·s, and 0.2443 Pa·s, respectively. It was proved that the introduction of HAWP not only increased the viscosity at the at low shear rates, but also decreased the viscosity and shear stress at high shear rates, which prompted the static stability of CA mortar without sacrificing the fluidity during construction.
Effect of HAWP on the fluidity of CA mortars. High fluidity of CA mortar was considered as an assurance for good pouring. Generally, superplasticizer increases fluidity, but causes high separation rate and bleeding. The fluidity of CA mortar containing different addition levels of hydrophobic associative polymer were shown in Fig.3. With the hydrophobic associative polymer dosage is gradually increased, the fluidity of CA mortar was little changed firstly, have a good maintained. When the HAWP addition level was 3‰, the fluidity of CA mortar was about 120s, which have gone beyond the construction requires. It can be seen that the sample at low doses could be regarded as fluidity good which is a very important parameter for CA mortar.
Effect of HAWP on the Separation properties of CA mortars. The effect of HAWP on the separation rate of CA mortar was shown in Figure 4. It can be seen that the separation rate of CA mortar decreased significantly when mixed with hydrophobic associative polymer. The separation rate was 3.7% without HAWP, which did not fulfill the specification demand of 3%. However, it reduced to 0.8% with 3‰ of HAWP. From this, it is thought that the CA mortar with HAWP shows better separation resistance.

It can be seen that the HAWP present significant influence on the viscosity of CA mortar. At the lower shear rate, strong intermolecular association between HAWP were formed because of the effect of electrostatic, hydrogen bonding and hydrophobic interaction, resulting viscosity increased sharply with the increase of polymer concentration. This can improve the CA mortar in static stability conditions and reduce the separation rate.

The mechanism of HAWP on CA mortars. The micelles could be formed by the lipophilic groups on HAWP in water, which adsorbing latex particles to enhance the structure. The physical cross linking structure could be formed by the bridging particle of HAWP macromolecular. The mesh structure was destroyed in the shear field gradually, so the system of flow properties could be controlled. With the increase of the shear rate, the intermolecular association of HAWP was destroyed due to its weak (physical) interactions, resulting viscosity decreased. This is beneficial for CA mortar construction.

CONCLUSIONS

The following conclusions were determined based upon the limited experimental data presented in this research project:

(1) The addition of hydrophobic associative polymer improves the viscosity and shear stress of CA mortar to some extent. The optimum quantity is 2‰.

(2) The hydrophobic associative polymer can improve the segregation resistance of CA mortar without sacrificing the fluidity.
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REFERENCES


