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Preparation of Latent Heat Materials Used in Asphalt Pavement and Theirs' Controlling Temperature Performance

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Abstract: In order to solve rutting diseases of asphalt concrete pavement, latent heat materials for asphalt pavement were prepared and theirs' controlling temperature performance were studied. Phase change materials (PCM), which were fitted to thermal environment of road were selected, phase change asphalt, diatomite powder and pottery sand granular composite phase change materials (CPCM) were prepared by three kinds of import modes. The CPCM were chosen by comparing the performance of above mentioned materials. Latent heat asphalt mixture (LHAM) was made by replacing mineral powder and fine aggregate with CPCM. Its controlling temperature ability was tested by temperature monitor system. The results show that, comparing to general asphalt mixture, LHAM can reduce temperature to 8-10℃. Therefore, LHAM has a good effect on adjusting road temperature.

Introduction

The rutting problem of asphalt concrete pavement has bored road transport administrators in the past few years, it is urgent to seek scientific and effective methods to solve the problem. The asphalt mixture is a viscoelastic material, the main factors which affect its mechanical properties are loading and temperature. Loading conditions are not easy to control, so temperature becomes the dominant factor to solve rutting. For a long time, the researchers have focused on improving temperature stability of asphalt and asphalt mixture, asphalt modifing, adding fiber and optimizing gradation and so on measures have been put forward [1-2]. All methods have changed asphalt pavement's temperature passively. Although they have solved some problems in certain domain and condition, temperature-related diseases of asphalt pavement are still very serious. Therefore, the paper was from the angle of improving temperature status of asphalt pavement, latent heat materials used in asphalt pavement were prepared, theirs' temperature performance were tested. The organic phase change materials (OPCM) were imported into inorganic porous materials to prepare composite phase change materials (CPCM). The latent heat asphalt mixture (LHAM) was prepared by mixing CPCM into asphalt mixture through different channels. CPCM is used to absorb heat of pavement constantly. Because of appropriate phase change temperature and high phase change latent heat, its self-thermostat effect performance is great.

Preparation of Latent Heat Materials Used in Asphalt Pavement

Phase change materials selection The phase change materials (PCM) can change phase with temperature and provide phase change latent heat (PCLH). Phase change materials can be divided into four categories which are solid-solid, solid-liquid, solid-gas and liquid-gas [3-4].

The commonly used OPCM are waxes, paraffins, fatty acids, salts, alcohols and so on. Theirs solid forming are good. They are not prone to super cooling and phase separation[5]. The corrosivity of them are less. Theirs performance are more stable. Considering factors which like phase change temperature, phase change latent heat, thermal conductivity coefficient, volumetric change rate, volatility, boiling point and so on, myristic acid, palmitic acid, PEG 4000 are chosen and the thermal properties parameters are shown in Table 1. For example, latent heat materials the road used require phase change temperature 45 ~ 65 ° C. Latent heat and thermal conductivity are as much as possible. Volumetric change rate before and after phase change is as small as possible. Volatile temperature is greater than 180 ° C.

Tab.1 The Thermal Parameters of Organic Phase Change Materials

Sample	Phase change temperature (℃)	Phase change latent heat (J/g)	Thermal conductivity (w/m·k)
Myristic acid	49-51	141.48	0.159/0.162/0.165
Palmitic acid	61～64	164.79	0.159/0.162/0.165
PEG4000	51～54	143.56	0.300/0.500

Import modes and performance analysis of CPCM

Direct incorporation Asphalt is a viscoelastic material. The direct incorporation of the OPCM has a bad effect on its road performance. The three indicators of 10%, 20% and 30% three concentrations of phase change modified asphalt (PCMA) was determined, results show in Figures 1 to 3.

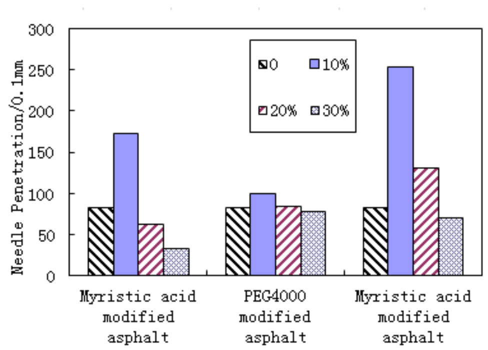


Fig.1 Needle Penetration of PCMA with Different Concentrations

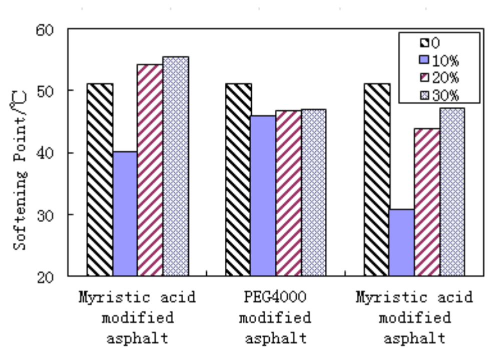


Fig.2 Softening Point of PCMA with Different Concentrations

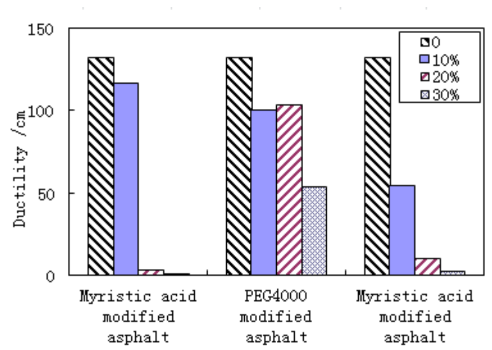


Fig.3 Ductility of PCMA with Different Concentrations

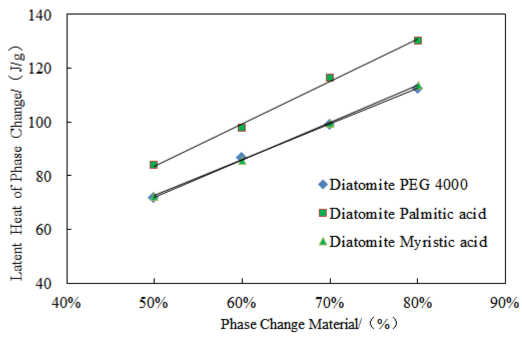


Fig. 4 Relationship Between PCLH and Import Volume of Power CPCM

Figures 1 to 3 indicate that, the direct incorporation of palmitic acid, PEG 4000 and myristic acid has a bad effect on the three indicators of asphalt, especially the ductility, The content of palmitic acid and myristic acid are 20% and 30% respectively, the ductility of PCMA are much lower, the corresponding adhesion and toughness are poor. Comparatively speaking, the asphalt three indicators of PEG4000 PCMA has a less impact. However, the phase change temperature of PEG4000 is 51~54℃, it will turn into a liquid when reaches the temperature and lose viscoelasticity. Therefore, the import mode is abandoned.

Vacuum import The diatomite power composite phase change materials (CPCM) were prepared by vacuuming diatomite and importing OPCM into porous pore of it, the import uniformity was tested by DSC and the results are shown in Figure 4.

The results in Figure 4 indicate that the latent heat of diatomite power CPCM increases linearly with the increase import volume of OPCM, the uniformity is great. When the import volume of palmitic acid reachs critical value-60%, latent heat is 97.74J / g, phase change thermostat is good.

Vacuum import and encapsulation The pottery sand granular composite phase change materials (PSGCPCM) were prepared by vacuuming pottery sand and importing OPCM into porous pore of it. The import uniformity was tested by DSC and the results are shown in Figure 5.

The results indicate that the latent heat of PSGCPCM increases linearly with the increase import volume of OPCM, the uniformity is great. When the import mass ratio of palmitic acid reachs critical value-30%, latent heat is 50.93J / g, phase change thermostat is good.

The above analysis shows that the direct incorporation of OPCM reduces the pavement performance. In order to reduce the impact on the asphalt road performance, The OPCM is import into power diatomite and granular pottery sand, the import mode is very simple, inorganic porous material shields OPCM to some extent, and reduce the impact of the spill on the asphalt pavement performance, and phase change thermostat is good.

In order to guarantee asphalt mixture's pavement performance and has as much latent heat as possible, powder diatomite palmitic acid (PDPA) and granular pottery sand palmitic acid (GPSPA) CPCM were prepared, mineral powder and fine aggregate were replaced with the same volume, PDPA and GPSPA were mixed with asphalt mixture to prepare the latent heat of asphalt mixture.

Preparation of the latent heat asphalt mixture (LHAM)

For multi-layer pavement, rutting and other high temperature disease are generally caused by the deformation of the middle and underside layers[1]. the upper layer of asphalt concrete pavement get sunlight and contact with air directly[6-7], hence, The application of LHAM in the upper layer can be an effective protection for the middle and underside layers by maintaining temperature below the phase change temperature. Thus, the rutting could be effectively inhibited. Therefore, AC-16 which is commonly used in the upper layer was selected to prepare LHAM, the mixture gradation use gradation median. In the gradation, fine aggregate of 1.18mm and 0.6mm are substituted with the same volume by corresponding particle size pottery sand palmitic acid CPCM, meanwhile mineral power are also replaced with the same volume by powder diatomite palmitic acid CPCM.

Study of LHAM' Self-tune Temperature Effect

Laboratory and Field Temperature Testing Methods The rutting specimen were put at room temperature for 24h. They were demoulded and put into the solar thermal temperature controlling box. Each specimen was tiled 20mm thick earth soil and the gap was filled with earth soil and tamp. When the sensor displays both temperature are almost the same, dysprosium lamp [8] was opened and the temperature changes over time was recorded. The testing equipment is shown in Figure 7.

The asphalt mixture rutting specimen were put on the roof so that they could be directly exposed to sunlight. Sensor was used ditto, test and record the temperature changes over time, as shown in Figure 8.

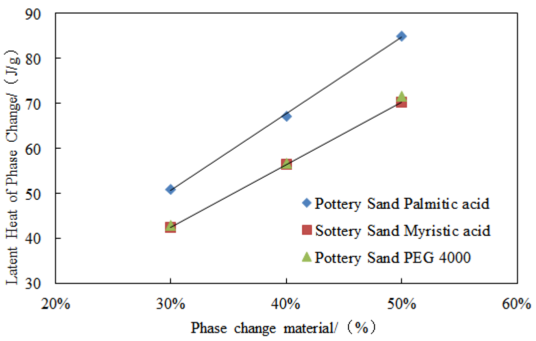
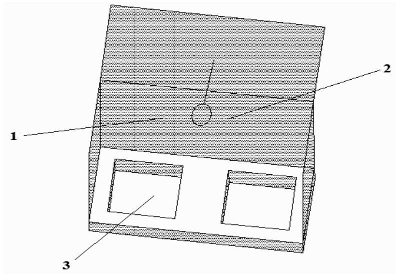


Fig.5 Relationship Between PCLH and Import Volume of Granular CPCM



1-Insulation polystyrene board 2-Adjustable power dysprosium lamp 3-Rutting groove

Fig.6 Schematic Diagram of Solar Thermal Temperature Controlling Box

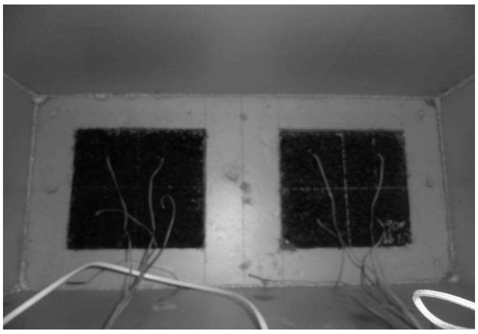


Fig.7 Laboratory Temperature Acquisition

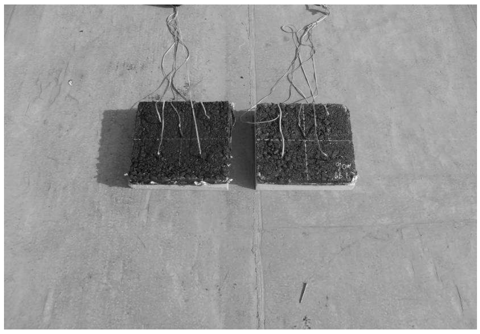


Fig.8 Field Temperature Acquisition

Evaluation of Laboratory and Field Thermostat Effect Figure 9 indicates that the temperature of asphalt mixture rutting specimen and PCAM rutting specimen increase with time, the temperature of the former is always higher than that of the latter one.

Figure 10 indicates that the temperature difference of the two rutting specimens increased constantly with time, at the time of 460min, the LHAM rutting specimen achieved the overall phase change temperature-59.1℃, and the temperature difference between the two specimens achieved the Maximum value-7.6℃. The results show that the CPCM in the latent heat asphalt mixture rutting specimen had been completely phase changed, fully absorbed heat and reached the saturation point. After that point, temperature difference between the two specimens decreased gradually.

Figure 11 indicates that PCAM rutting specimen's temperature rise rate is significantly less than the asphalt mixture rutting specimen's at the beginning of the period. When the overall temperature achieved the phase change temperature (PCT), temperature rise rate of PCAM rutting specimen instant mutated to be greater than asphalt mixture rutting specimen’s. After that point, both moved closer and tended to be equal at last. Analyze the reason, the latent heat asphalt mixture material rutting specimen achieve to the phase change temperature from the surface to the center. However, each time reach the temperature, the corresponding CHPM will instantly absorb a lot of heat, inhibit temperature rise. To start from the Macro-view, the performance appears that the temperature rise rate of latent heat asphalt mixture rutting specimen is significantly less than the asphalt mixture rutting specimen. When CPCM of LHAM rutting specimen entire happen phase change. Due to the overall temperature of LHAM rutting specimen are quite different from the air's, so the transient performance is that the temperature rise rate is greater than the asphalt mixture rutting specimen's. And then, with the temperature difference between LHAM and the air decreases, both temperature rise rate are gradually closer and tend to be equal at last.

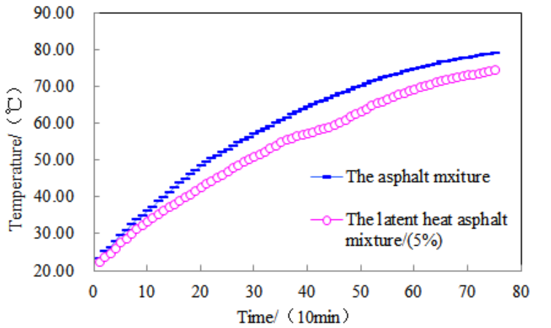


Fig.9 Laboratory Temperature-time Curve

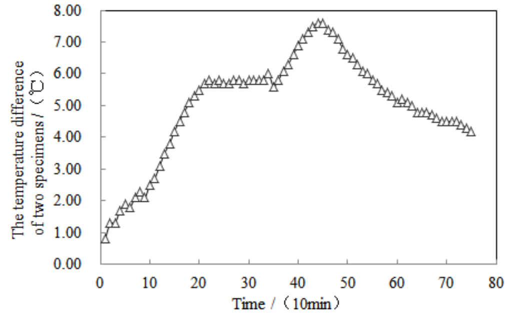


Fig.10 Laboratory Temperature difference-time Curve

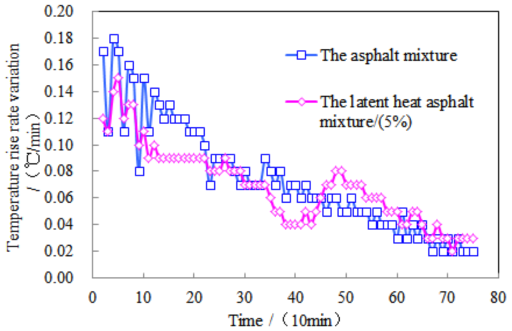


Fig.11 Laboratory Temperature Rise Rate Variation with Time

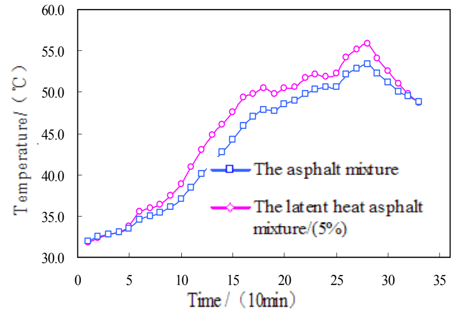


Fig.12 Field Temperature-time Curve

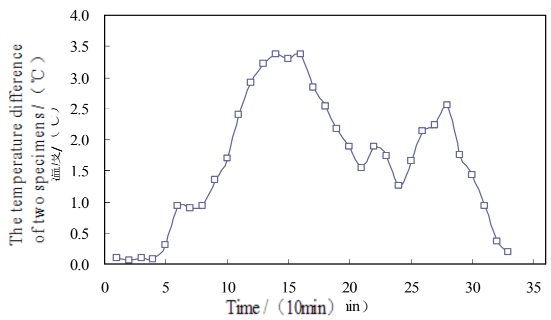


Fig.13 Field Temperature difference-time Curve

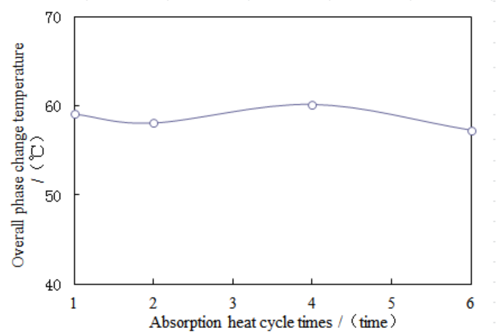


Fig.14 Relationship Between Laboratory PCT and Absorption Heat Cycle Time

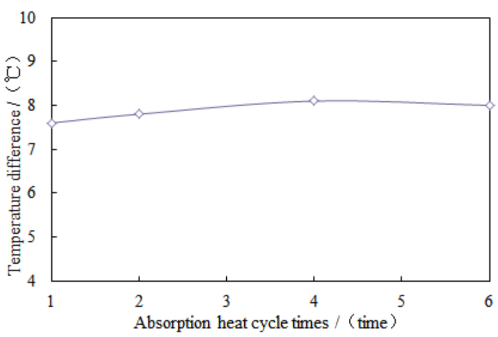


Fig.15 Relationship Between Laboratory Max-temperature Difference and Absorption Heat Cycle Times

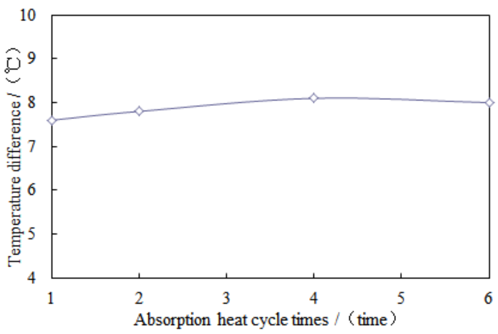


Fig.16 Relationship Between Field Maximum-temperature Difference and Absorption Heat Cycle Times

Evaluation of Laboratory and Field Thermostat Effect Figure 12 indicates that temperature of both specimens increase and then decrease with time, and temperature of the former is always greater than that of the latter one. But the curve has a big fluctuation. Analyze reasons, due to the changing of wind speed size and solar radiation intensity.

Figure 13 indicates that the temperature difference of asphalt mixture rutting specimen and PCAM rutting specimen increase constantly with time, and achieve to the maximum-3.4℃ at the time of 160 min. The effect of the phase change mixture on temperature is not good enough. Analyze reason, the asphalt mixture didn't achieve to overall phase change temperature (based on laboratory experiment it is 58.5~60.5℃), majority of CPCM phase change heat-absorbing potential has not been effectively carried out.

Laboratory and field phase change fatigue thermostat effect Figure 14 and 15 indicate that the change of the phase change temperature and the thermostat effect with the increase in absorption heat cycle is small. It shows that the phase change reversibility of LHAM is great.

Figure 16 indicates that the natural phase change fatigue of rutting specimen affect the results because of bad weather. The temperature didn’t meet the overall phase change temperature range (58.5-60.5℃). So thermostat effect is poor and the maximum temperature difference is smaller.

Conclusions

When PCMA is at PCT or higher temperature range, the viscoelastic properties and corresponding road performance is deeply influenced, so the import mode is abandoned.

The OPCM is imported into inorganic porous material by using vacuum adsorption method and the powder and granular CPCM is prepared. The incorporation method have little impact on pavement performance of asphalt mixture. The incorporation is larger and thermostat is greater.

Laboratory simulation results indicate that when import mass ratio of OPCM was 5%, the maximum temperature difference of the PCAM and asphalt mixture was 7.6℃, the corresponding overall PCT was 59.1℃, At that time, the specimen show great slow temperature rise effect and good phase change reversibility.

The field experimental results indicate that the import mass ratio of OPCM is 5%, compare to the asphalt mixture, the maximum temperature difference was 3.4 ° C, the phase change reversibility is great.

The development of higher strength and greater porosity aggregate, importing of OPCM and packaging technology are further problems to be solved, meanwhile, the CPCM's long-term stability is also one problem to be considered.

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