Study on the Applicability of Phase Change Energy Storage Materials in Asphalt Pavement

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Abstract: In order to optimize the phase-change energy storage materials for asphalt pavement and analyze the feasibility and applicability of phase-change energy storage materials for asphalt pavement, the experimental methods of thermogravimetric analysis (TG) and Fourier infrared spectroscopy (FT-IR) were adopted. The thermal stability, chemical stability and chemical compatibility of various phase change energy storage materials were tested and analyzed. The results show that the fatty acids, stearic acids and fatty alcohols showed significant weight loss at 200℃. PEG and DTC phase change materials showed no mass loss at 200℃ and had good thermal stability. PEG2000 and DTC have no chemical changes after high temperature treatment, and PEG2000, DTC and SBS modified asphalt are physical blend, and the chemical compatibility with asphalt is good. Crystalline hydrated salts, paraffin, fatty acid, stearic acid, fatty alcohol phase change materials are not suitable for asphalt pavement, PEG organic phase change materials and DTC composite phase change materials can be used for intelligent temperature control asphalt pavement research.

1. Introduction

In recent years, the proportion of asphalt pavement in China's highway reaches more than 90% and shows an increasing trend year by year. Because asphalt pavement is easy to absorb heat and store heat under sun irradiation and high temperature, the rise of pavement temperature leads to high temperature disease, and at the same time, it intensifies the urban heat island effect.[1][2] In addition, the asphalt pavement is easy to frost, freeze and snow under the freezing climate of low temperature rain and snow in winter, which also seriously affects the safety of road transportation and causes huge economic loss and social impact.

In this context, it is urgent to research and develop or explore some kind of material added to asphalt pavement to change its temperature field, so that the temperature of asphalt pavement can be maintained within the use temperature range. In view of this, road researchers have gradually come up with the idea of applying phase change heat storage materials to highway asphalt pavement, that is, using its phase change characteristics, releasing or absorbing heat in asphalt pavement, avoiding the asphalt pavement to produce high and low temperature diseases and playing the role of anti-freezing ice. However, there are many kinds and forms of phase-change energy storage materials, and there are few phase-change energy storage materials with practical application value. It is necessary to further test the performance.
of phase-change energy storage materials according to the use characteristics of asphalt pavement, so as to optimize the phase-change energy storage materials for asphalt pavement \[^3\]. Therefore, according to the characteristics of asphalt pavement, this paper puts forward the technical requirements of phase change energy storage materials for asphalt pavement, and selects a variety of phase change energy storage materials for indoor test, screening out the suitable phase change energy storage materials for asphalt pavement, and analyzes the applicability of phase change energy storage materials for asphalt pavement. The research results lay a foundation for the promotion of phase-change energy storage materials in asphalt pavement, and have important practical significance for solving the temperature problems of asphalt pavement and prolonging the service life of pavement.

2. **Experiment**

2.1. **Main Raw Materials**

52# semi-refined paraffin wax (melting point is about 52°C) : granular, industrial grade, products of Nanjing Bojiang Chemical Co., Ltd. 58# fully refined paraffin wax (melting point is about 58°C) : block, industrial grade, products of Guangdong China Southern Union Energy Co., Ltd. Lauric acid (lauric acid) : white needle crystal, industrial grade, products of Shanghai Lianji Chemical Co., Ltd. Stearic acid (octadecanoic acid) : granular, industrial grade, Zibo Yingzhao Chemical Technology Co., Ltd. Products; Tetradecyl alcohol: colorless liquid, industrial grade, products of Shanghai Beite Chemical Co., Ltd. Neopentylene glycol: white crystalline solid, industrial grade, product of Nanjing Huahong Chemical Co., Ltd. Polyethylene glycol (PEG2000 and PEG4000) : sheet, industrial grade, product of Shanghai Lianji Chemical Co., Ltd. DTC composite phase change material, granular, millimeter grade, Beijing Qintian Technology Group Co., Ltd.; SBS modified asphalt: product of Jiangsu Baoli International Investment Co., Ltd.

2.2. **Main equipment and instruments**

Netzsch-STA449C synchronous thermal analyzer, the product of Germany Nechi Instrument Manufacturing Co., Ltd.; PE Spectrum Infrared Spectrometer is a product of Perkin Elmer Enterprise Management (Shanghai) Co., Ltd.

2.3. **Preparation of PEG, DTC and asphalt blends**

The SBS modified asphalt was heated to the melting state of 170°C, and the dry PEG and DTC phase change energy storage materials were slowly added into the asphalt in proportion. Then the asphalt was stirred for 10min at a stirring speed of 2000r/min and the temperature was maintained at about 165°C. After the stirring, the asphalt was shears for 10min at a shear rate consistent with the stirring speed. PEG and asphalt blends and DTC and asphalt blends can be prepared respectively\[^4\].

2.4. **Performance Test**

(1) thermal stability analysis. Thermogravimetric analysis (TG) test is one of the methods to characterize the thermal stability of phase-change energy storage materials. It was tested by Netzsch-STA449C synchronous thermal analyzer at room temperature to 250°C with a heating rate of 10°C/min. Protective gas and scavenging gas are high pure nitrogen, and the flow rate is 20ml/min.

(2) chemical stability analysis. Fourier Transform Infrared Spectroscopy (FT-IR) was used to analyze the changes of molecular structure and chemical composition of PEG and DTC phase change materials before and after high temperature treatment, and to investigate the stability of chemical properties.

(3) Chemical compatibility analysis. Fourier Transform Infrared Spectroscopy (FT-IR) was used to test PEG and asphalt blendings and DTC in asphalt blendings.
3. Results and discussion

3.1. Thermal stability analysis
TG test results of paraffin, fatty acid, stearic acid, fatty alcohol, PEG and DTC are shown in Fig. 1-6 below.

(a) 52# Paraffin
(b) 58# Paraffin
Fig. 1 TG curve of paraffin phase change energy storage materials

(a) Lauric acid
(b) Stearic acid
Fig. 2 TG curve of fatty acid phase change materials

Fig. 3 TG curve of tetradecanol
Fig. 4 TG curve of neopentylene glycol

(a) PEG2000
(b) PEG4000
Fig. 5 TG curves of PEG phase change energy storage materials
According to the TG curves in Fig. 1 to Fig. 6, 52# and 58# paraffin wax began to show weightlessness at 150℃ and it was not obvious, but showed a tendency of thermal decomposition as the temperature increased. The weight loss rates at 200℃ were 2.37% and 2.85%, respectively, with a small mass loss. The weight loss of lauric acid and stearic acid was not obvious at 160℃, but the weight loss of lauric acid and stearic acid was obvious at 200℃, the weight loss rate was 33.76% and the weight loss rate of stearic acid was 4.27%. Tetradecyl alcohol begins to lose weight at about 170℃, and the weight loss rate reaches 6.66% at 200℃. Neopentylene glycol began to show thermal weightlessness at 100℃, and showed obvious weightlessness at 200℃ with a weightlessness rate of 99.9%. Although PEG2000 and PEG4000 begin to experience thermal weightlessness at 80℃, their mass loss is small, and the weightlessness rate increases slowly with the increase of temperature. The weightlessness rate at 200℃ is 2.92% and 1.53%, respectively. The thermal weightlessness of DTC began to appear at 178℃, and the weight loss rate was 41.39% at 400℃ and 3% at 200℃, with no loss basically. This indicates that fatty acids and fatty alcohols can not withstand the high temperature of 200℃, while paraffin, PEG and DTC phase change heat storage materials can withstand the high temperature of 200℃ without decomposition. Considering that paraffin will weaken the performance of asphalt and affect the pavement performance of asphalt pavement, PEG and DTC are recommended to be used as phase change heat storage materials for asphalt pavement, and paraffin, fatty acid and fatty alcohol should be avoided directly.

3.2. Chemical stability analysis

FT-IR test results of PEG and DTC phase change energy storage materials before and after high temperature treatment at 200℃ are shown in Figure 7 and Figure 8 below.

As can be seen from Fig. 7, compared with PEG2000 and DTC at the normal temperature respectively and those at the high temperature treatment at 200℃ for 1h, the position of the whole characteristic absorption peak does not change, indicating that PEG2000 and DTC, the efferent energy storage materials, will not undergo chemical changes after high temperature treatment, and their chemical properties are relatively stable[5].
3.3. Chemical compatibility analysis

The components of phase-change asphalt mixture should not undergo chemical reaction to ensure its phase-change heat storage function. Considering the stable properties of mineral material and filler, the main analysis is whether there will be chemical reaction between phase-change energy storage materials and asphalt. FT-IR was used to test the blend of PEG and modified asphalt and the blend of DTC and modified asphalt respectively. The test results are shown in Figure 9 and Figure 10 below.

![Fig. 9 FT-IR diagram of PEG2000 and asphalt blend](image1)

![Fig. 10 FT-IR diagram of DTC and asphalt blend](image2)

As shown in Fig. 9 and Fig. 10, compared with the spectrum of PEG2000 and SBS-modified asphalt, no new characteristic absorption peak was generated in the spectrum of PEG2000 and SBS-modified asphalt, and the original characteristic peak did not disappear. Compared with the spectrum of SBS-modified asphalt, the spectrum of DTC and SBS-modified asphalt did not produce new characteristic absorption peaks, nor did the original characteristic peaks disappear. The results show that there is no chemical reaction between PEG2000, DTC and SBS modified asphalt, but physical reaction is the main reaction. Therefore, the application of PEG2000 and DTC phase change energy storage materials in asphalt system will not affect its phase change heat storage function\(^\text{[6]}\).

4. Conclusion

(1) TG test shows that fatty acid, stearic acid and fatty alcohol phase change energy storage materials show obvious weight loss in the test temperature range, while PEG and DTC phase change energy storage materials have no mass loss at 200\(^\circ\)C, so PEG and DTC phase change heat storage materials can withstand the high temperature of 200\(^\circ\)C without decomposition. To meet the construction temperature requirements of hot mix asphalt mixture.

(2) FT-IR test showed that the characteristic peaks of PEG2000 and DTC treated at 200\(^\circ\)C for 1h did not produce new characteristic peaks, and the original characteristic peaks did not change, indicating that high temperature did not have an effect on PEG and DTC, that is, no chemical changes occurred after high temperature treatment, and the chemical properties were stable. PEG2000, DTC and SBS modified asphalt are all physical blends, that is, PEG2000, DTC and asphalt have good chemical compatibility, the application of PEG2000, DTC will not affect the phase change heat storage function of PEG and DTC.

(3) PEG organic phase change energy storage materials with low undercooling and no phase separation and DTC composite phase change materials are recommended to be used as the phase change heat storage materials for asphalt pavement. The use of crystalline hydrates, paraffin, fatty acid, stearic acid and fatty alcohol phase change energy storage materials should be avoided.

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