Study on the effect of phase change energy storage material on the performance of asphalt mixture

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Abstract: Aiming at the high and low temperature diseases of asphalt pavement, in order to improve the environmental adaptability of asphalt pavement, the road phase change temperature-regulating composite material (DTC) was selected to prepare phase change asphalt mixture, and the pavement performance of phase change asphalt mixture was studied by indoor temperature rise and drop test, rut test, immersion Marshall test, freeze-thaw splitting test and low temperature bending test. The results show that DTC reduces the rate of rise and drop during the indoor heating process. DTC can effectively absorb heat for 140min at 40℃ and can effectively release heat for 80min at -18℃. With the increase of DTC content, the dynamic stability, residual stability and splitting strength ratio of phase change asphalt mixture show a trend of decrease, while the low temperature failure strain shows a trend of first increase and then decrease.

1. Introduction

Asphalt pavement with good flatness, comfort and low noise advantages are widely used in highway and city road, but there is a high temperature rutting, low temperature cracking and low temperature setting ice temperature, using asphalt modification, adding fiber, the optimization of gradation composition technology is difficult to solve temperature of asphalt pavement diseases, therefore, need to explore new technical measures, The temperature of asphalt pavement can be improved actively to keep it within the reasonable temperature range with good performance of asphalt mixture for a long time[1].

Phase change materials are materials that use the heat absorbed or released during the Phase transition process to carry out latent heat storage, which can be used for heat energy storage and temperature control. Therefore, the latent heat characteristics of phase change energy storage materials can be used to add phase change energy storage materials to asphalt mixture, so as to achieve the purpose of actively regulating the use temperature of asphalt mixture, and explore new ideas for improving the adaptability of asphalt road to environmental changes[2].

In this study, on the basis of phase change materials research, DTC is added in the asphalt mixture preparation phase change composite asphalt mixture, using litre cooling test, rutting test and immersion Marshall test and freeze-thaw splitting test, low-temperature bending test of phase transition temperature of asphalt mixture to study the performance and road performance evaluation, The effect of phase change energy storage materials on the performance of asphalt mixture is analyzed.
2. Test

2.1. Main Raw materials
Road phase change temperature-regulating composites (DTC), products of Beijing Qintian Science and Technology Group Co., LTD. Coarse aggregate, particle size of 1# sample (9.5-13.2) mm, 2# sample (4.75-9.5) mm, 3# sample (2.36-4.75) mm, jiangsu Xingyuan Mining Co., LTD. Fine aggregate, basalt ore material with diameter of 0-2.36mm, product of Pengze County Honghao Mashan Mining Co., LTD.; The filler is the powder obtained by grinding limestone alkali stone, which is the product of Gaozi Tangjiazhuang machine clip factory in Dantu District, Zhenjiang city. SBS modified asphalt, Jiangsu Baoli International Investment Co., Ltd. Lignin fiber, relative density of 1.13, Jiangsu Shiteng Engineering Materials Co., LTD. The above mineral processing materials and asphalt quality are combined with the relevant requirements of "Technical Code for Construction of Highway Asphalt Pavement" (JTG F40-2004).

2.2. Main Equipment
Automatic asphalt Rutting machine, Hebei Yaoyang Instrument equipment Co., LTD. DFMS-9 asphalt mixture stability tester, Nanjing Tuoxing Instrument and Instrument Research Institute products; WDW-LH low temperature bending test system for asphalt mixture is a product of Jinan Yinuo Century Test Instrument Co., LTD.

2.3. Preparation of phase change asphalt mixture
Using SMA-13 asphalt mixture grading, ore ratio is 9.5-13.2mm: 4.75-9.5mm: 2.36-4.75mm: 0-2.36mm: powder =38:38:0:14:10, the optimal ratio of oil to stone is 5.9% (of mineral mass), the content of lignin fiber is 0.03% (of mixture mass), and the content of DTC is the percentage of the mass of the mixture. According to JTG F40-2004, the phase change energy storage asphalt mixture was prepared.

2.4. Performance Test
Temperature regulation performance test. Temperature regulation performance test. First of all, the rutting board specimens of phase change asphalt mixture and ordinary asphalt mixture are formed, and two temperature sensors are installed in the rutting board respectively. For the heating test, the rutting board was placed in an oven for heating, and the oven temperature was 40℃. The temperature was recorded every 10 minutes until the internal temperature of the rutting board reached 40℃. For the cooling test, the rutting board specimen heated to 40℃ was immediately taken out and placed in the refrigerator of -18℃, and then the temperature was recorded every 10 minutes until the internal temperature of the phase change asphalt mixture rutting board and the ordinary asphalt mixture rutting board was the same.

High temperature performance test. The rutting test machine was used to test asphalt and Asphalt Mixture in Highway Engineering according to JTG E20-2011. The test temperature was 60℃ and the wheel pressure was 0.7mpa. Water stability test.

Marshall stability tester was used for the test in accordance with JTG E20-2011. The test temperature was 25℃ and the loading rate was 50mm/min. Low temperature crack resistance test.

The low-temperature bending testing machine was used to test in accordance with JTG E20-2011. The test temperature was -10℃±0.5℃ and the loading rate was 50mm/min.

3. Results and discussion

3.1. Performance of temperature regulation
In accordance with the above temperature regulation performance test method, the temperature change curve is shown in the following figure.
3. The above test results show that:

1) In the indoor heating process, the internal temperature of phase change asphalt mixture is always less than the internal temperature of ordinary asphalt mixture. When the content of DTC is 0.3%, 0.6% and 0.8%, compared with ordinary asphalt mixture, the maximum cooling range is 3.2℃, 3.3℃ and 3.9℃, respectively. With the increase of DTC content, the greater the cooling range. With the extension of time, the cooling amplitude of phase change asphalt mixture decreases. After 140min, the internal temperature difference between phase change mixture and ordinary mixture is less than 0.5℃. DTC in the indoor temperature of 40℃, the effective continuous heat absorption time of at least 140min.

2) In the indoor cooling process, the internal temperature of phase change asphalt mixture is always higher than that of ordinary asphalt mixture, and the more the mixture, the greater the temperature difference between phase change asphalt mixture and ordinary mixture. When the content of DTC is 0.3%, 0.6% and 0.8%, compared with ordinary asphalt mixture, the maximum heating range is 0.3℃, 0.5℃ and 0.8℃, respectively. At 80min, the internal temperature of phase-change asphalt mixture is the same as that of ordinary asphalt mixture. At this time, the stored heat of DTC has been released, indicating that the effective heat release of DTC can last for 80min under the condition of -18℃.

3.2. High temperature performance
The rutting board was formed with phase change asphalt mixture, and the rutting test was carried out according to the JTG E20-2011 test regulations. The results are shown below.

![Figure 3. Rutting test results of phase change asphalt mixture](image-url)
oven for insulation for no less than 5h before the rutting test. Because the insulation temperature of 60℃ has exceeded the initial temperature of DTC, and the insulation time is as long as 5h, the phase transformation of phase change particles has been completed in this process, and the heat is no longer absorbed. And the wax substance contained in DTC also has a certain degree of influence on the high temperature performance of the mixture[8][9][10].

3.3. Water stability
The water damage resistance of phase change asphalt mixture was analyzed by immersion Marshall test and freeze-thaw splitting test. The test results are shown in the figure below.

![Figure 4. Marshall test results of phase change asphalt mixture soaked in water](image)

![Figure 5. Freeze-thaw splitting test results of phase change asphalt mixture](image)

The above test results show that the residual stability and splitting strength ratio of phase change asphalt mixture decrease gradually with the increase of DTC content, but both can meet the requirements of JTG F40-2004 specification. When the content of DTC is 0.3%, 0.6% and 0.8%, the residual stability of phase change asphalt mixture is reduced by 2.6%, 5.9% and 8.2%, respectively, and the splitting strength ratio of phase change asphalt mixture is reduced by 2.4%, 3.4% and 4.9%, respectively, compared with that of ordinary asphalt mixture. In conclusion, the residual stability and splitting strength ratio of phase change asphalt mixture decrease gradually with the increase of DTC content, but can meet the requirements in the range of DTC content ≤0.8%.

3.4. Low temperature crack resistance
Low temperature trabecular test was used to analyze the low temperature crack resistance of phase change asphalt mixture. The test results are shown in the figure below.

![Figure 6. Bending test results of phase change asphalt mixture at low temperature](image)

The above results show that: The low temperature failure strain of phase change asphalt mixture increases first and then decreases with the increase of DTC content. The low temperature failure strain of the mixture increases by 2.4% with 0.3% DTC content, and the low temperature failure strain of the mixture decreases by 5.5% with 0.6% DTC content. With the addition of 0.8% DTC, the low
temperature failure strain of the mixture decreases by 8.7%.

According to the temperature regulation performance of phase change asphalt mixture, DTC can effectively exothermic for 80min at -18℃ indoor conditions, and can continue to exothermic for at least 140min at 4℃ indoor low temperature environment, indicating that the internal temperature of phase change asphalt mixture is always above -10℃ in the process of -10℃ environmental insulation. Therefore, the low temperature failure strain of 0.3% phase change asphalt mixture increases, indicating that the heating performance of DTC plays a leading role. When the content of DTC is more than 0.6%, the low temperature failure strain of the phase change asphalt mixture shows a decreasing trend, indicating that the paraffin and other components of DTC play a dominant role in the side effects of asphalt[11].

4. Conclusion

(1) In the indoor heating process, when the DTC content is 0.3%, 0.6%, 0.8%, the maximum cooling range of phase change asphalt mixture compared with ordinary asphalt mixture is 3.2℃, 3.3℃, 3.9℃. With the increase of DTC content, the greater the cooling range, the effective heat absorption of DTC can last for 140min. In the indoor cooling process, when the DTC content is 0.3%, 0.6%, 0.8%, compared with ordinary asphalt mixture, the maximum temperature rise range of phase change asphalt mixture is 0.3℃, 0.5℃, 0.8℃. The effective heat release of DTC can last for 80min at -18℃.

(2) With the increase of DTC content, the dynamic stability, residual stability and splitting strength ratio of phase change asphalt mixture showed a trend of decrease, but DTC content ≤0.8% range, can still meet the requirements of JTG F40-2004 specification.

(3) The low temperature failure strain of the phase change asphalt mixture increases first and then decreases with the increase of DTC content. The 0.3% DTC content increases the low temperature failure strain of the asphalt mixture, indicating that the heating performance of DTC plays a leading role. When the content of DTC is more than 0.6%, the low temperature failure strain of the phase change asphalt mixture shows a decreasing trend, indicating that the paraffin and other components of DTC play a dominant role in the side effects of asphalt.

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