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Adhesion Characteristics of Silane Coupling Agent Modified Foamed Asphalt in the Monsoon Freezing Zone

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Abstract

To evaluate the adhesion of silane coupling agent-modified foam asphalt under the monsoon freezing zone. In this paper, the adhesion of matrix asphalt (AH90), foamed asphalt (FAH90) and silane coupling agent-modified foamed asphalt (MFAH90) after salt-freeze-thaw cycling is rated using the water-boiling method test and the rate of mass loss of each type of asphalt after the water-boiling method is calculated. The results show that with the increase of the number of salt-freezing and thawing cycles, the adhesion patterns of matrix asphalt, foamed asphalt and silane coupling agent modified foamed asphalt are similar, all showing a decreasing trend, in which the adhesion of foam asphalt decreases the most, and the adhesion of silane coupling agent modified foam asphalt has the smallest decreasing amplitude.It shows that silane coupling agent can improve the adhesion of foamed asphalt and effectively bridge the adhesion gap between hot-mix matrix asphalt and warm-mix foamed asphalt.

Keywords

Monsoon Freezing Zone; Silane Coupling Agent; Foamed Asphalt; Adhesion Properties.

1. Introduction

Road pavement construction is one of the main sources of energy consumption and carbon emissions. Asphalt pavements are widely used on all types of highways due to their advantages such as driving comfort and lack of dust, and their main component is the asphalt mixture. Asphalt mixtures can be divided into hot mix asphalt mixtures and warm mix asphalt mixtures according to the construction process. At present, the highway pavement is commonly used in hot mix asphalt mixtures, which need to be constructed at a high temperature of 150℃-180℃ environment. Hot mix asphalt mixture mixing and rolling process will produce a large number of harmful asphalt smoke, carbon dioxide and other harmful gases, not only to the health of the construction workers, but also in the pollution of the ecological environment at the same time exacerbate the formation of the greenhouse effect. Compared with the hot mix asphalt mixture, warm mix asphalt mixture construction temperature is about 30 ℃ lower, to a large extent, to reduce the mixture mixing and rolling process of asphalt fumes, carbon dioxide and other harmful gases, the health of construction workers and the environment is less harmful[1, 2].

Generally, warm mix asphalt technology is divided into three categories: surface-active warm mix technology, organic additive technology, and warm mix foam asphalt technology. Warm mix foamed asphalt technology is more economical, each production of 1 tonne of warm mix foam asphalt mixture compared with hot mix asphalt mixture saves 1 ~ 1.5kg of fuel, greatly improving the energy efficiency. Therefore, warm mix foam asphalt mixture has been widely used[3, 4].

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With the application of warm mix foamed asphalt mixture, a large number of engineering practical experience and research has proved that the water stability of foam asphalt mixture needs to be improved.

In the northeast monsoon freezing area of China, with high summer temperatures, low winter temperatures and heavy snowfall, the large amount of snow on the road affects road traffic. In order not to affect the road traffic, the road surface is often sprinkled with snow-melting salt in wintertime. Under the special environmental conditions, asphalt pavement is seriously damaged by salt erosion and water, which is mainly manifested as loose pavement, potholes and cracking, etc., which seriously affects the service life of asphalt pavement and traffic safety. Freeze-thaw cycling as an aggravated water damage severely restricts the application of foam asphalt mixtures in the monsoon freezing zone. Therefore, improving the water stability of foam asphalt mixtures by modifying foam asphalt with modified materials has become a priority in asphalt pavement research.

Silane coupling agent as a commonly used modifier to improve the bonding between materials[5-7]. In this paper, Silane coupling agent was used as a modification material for foam asphalt, and the adhesion of matrix asphalt, foam asphalt and Silane coupling agent modified foam asphalt was evaluated after different numbers of salt-freeze-thaw cycles, and the comparative analysis of the adhesion and attenuation law of each type of asphalt were comparatively analysed. For the Silane coupling agent modified foamed asphalt in the northeast monsoon freezing area application provides data reference and theoretical basis.

2. Materials and Method

2.1. Materials

The test matrix asphalt is 90# road petroleum asphalt(AH90), Its technical indicators are shown in Table 1. Foamed asphalt(FAH90) is foamed by adding 1.8% to 90# asphalt, Silane coupling agent modified foamed asphalt(MFAH90) is modified by adding 1.8% to 90# and then 0.5% Silane coupling agent.

Table 1. 90# asphalt technical indicators

Experimental projects	Measured value	Normative value
Needle penetration (25℃, 5s, 100g)/0.1mm	93	80-100
Ductility (15℃)/cm	>150	>100
Softening Point/℃	45.5	42-55
Solubility/%	99.97	>99.0
Flash point (open)/℃	306	>230
Density (25℃)/kg/m^3	1001.0	-
Wax content (distillation method)/%	1.91	<3.0

2.2. Method

(1) Preparation of specimens

On the basis of references and previous experience, salt solution erosion and freeze-thaw cycle were used to simulate the environmental characteristics of the Northeast Quarter Frozen Zone

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with low winter temperatures and snow-melting salt spread on the road surface, and salt-freeze-thaw cycle was applied to AH90, FAH90 and MFAH90 ,and are shown in Fig. 1-4.

Fig 1. Freeze-thaw cycle tester

Fig 2. Snow-melting salt solution

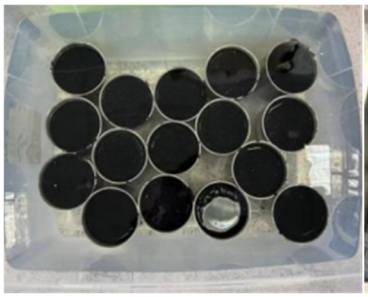

Fig 3. Asphalt immersed in salt solution

Fig 4. Asphalt placed in freeze-thaw cycler

(2)Boiling method

The boiled water test is often used to evaluate the adhesion of asphalt to aggregates. In this paper, the adhesion ratings of AH90, FAH90 and MFAH90 after 0, 5, 15 and 30 salt-freeze-thaw cycles were carried out using the water-boiling method test, and the asphalt mass loss rate after the water-boiling method test was calculated to compare and analyse the adhesion of various types of asphalt.

3. Result

(1) Adhesion grade

The adhesion ratings of the various types of bitumen were obtained by the observation method after the water boiling test, and are shown in Table 2

Table2. Adhesion ratings of various types of asphalt after salt-freeze-thaw cycles

Adhesion grade			
Number of salt-freeze-thaw cycles	AH90	FAH90	MFAH90
0	5	5	5
5	5	4	4
15	4	4	4
30	4	3	4

As can be seen from Table 2, the adhesion grades between AH90, FAH90, MFAH90 and aggregates decreased after salt-freeze-thaw cycles. FAH90 has the lowest adhesion rating, indicating that the foamed asphalt has the poorest adhesion properties to the aggregate.

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(2)Rate of loss of asphalt quality

Define $R = \frac{m_1 - m_2}{m_1}$

R- Rate of loss of asphalt quality;m_1 - Quality of asphalt specimens before boiling; m_2 -Quality of asphalt specimen after boiling.

The adhesion of three types of asphalt was evaluated using the rate of mass loss. In this test, each kind of asphalt need to parallel test 5 times, take its average value as the final asphalt quality loss rate results, all kinds of asphalt quality loss rate results are shown in Table 3.

Table 3. Mass loss rates of various types of asphalt

Rate of loss of asphalt quality (%)			
Number of salt-freeze-thaw cycles	AH90	FAH90	MFAH90
0	0.6909%	1.3330%	1.1757%
5	0.8144%	1.7006%	1.2560%
15	1.1252%	2.1067%	1.3826%
30	1.3815%	2.6391%	1.6079%

As shown in Table 3, the mass loss mass rate of AH90, FAH90, and MFAH90 gradually increased with the increase in the number of salt-freeze-thaw cycles. It shows that after salt-freeze-thaw cycles, the adhesion capacity and water stripping resistance of all types of asphalt to aggregates are gradually reduced. After 30 freeze-thaw cycles, AH90 specimens lost 1.3815% of their mass, FAH90 specimens lost 2.6391%, and MFAH90 specimens lost 1.6079% of their mass, which indicates that FAH90 has the worst adhesion to aggregates and resistance to water stripping. Comparing MFAH90 vs. FAH90, MFAH90 has better adhesion properties. It is shown that silane coupling agents can improve the adhesion of foam asphalt. In summary, the addition of silane coupling agent resulted in improved adhesion performance of foamed asphalt, and the adhesion of silane coupling agent modified foamed asphalt was similar to that of matrix asphalt.

4. Conclusion

In this paper, the adhesion of matrix asphalt (AH90), foamed asphalt (FAH90) and silane coupling agent-modified foamed asphalt (MFAH90) after salt-freeze-thaw cycling is rated using the water-boiling method test and the rate of mass loss of each type of asphalt after the water-boiling method is calculated. The following conclusions were drawn.

(1)The adhesion grades between AH90, FAH90, MFAH90 and aggregates decreased after salt-freeze-thaw cycles.

(2) The adhesion capacity and water stripping resistance of all types of asphalt to aggregates are gradually reduced after salt-freeze-thaw cycles.

(3) Silane coupling agents can improve the adhesion of foam asphalt

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