

Water Stability of Silane Coupling Agent Modified Foamed Asphalt Mixtures in the Monsoon Freezing Zone

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Abstract

In order to evaluate the effect of silane coupling agents on the water stability of foamed asphalt mixtures, In this paper, split tests were conducted to investigate the water stability of matrix asphalt (AH90) mixes, foamed asphalt (FAH90) mixes and silane coupling agent modified foamed asphalt (MFAH90) mixes after salt-freeze-thaw cycles. The results show that the split tensile strength ratios of all types of asphalt mixtures gradually decrease with the increase in the number of salt-freeze-thaw cycles. The TSR of MFAH90 exceeded that of AH90, indicating that the addition of silane coupling agent improved the water stability of the foamed asphalt mixture and compensated for the lack of water stability of the foam asphalt mixture.

Keywords

Monsoon Freezing Zone; Water Stability; Silane Coupling Agent Modified Foamed Asphalt Mixtures.

1. Introduction

Road pavement construction constitutes a significant source of energy consumption and greenhouse gas emissions. Among various pavement types, asphalt pavements have gained widespread application across all highway categories owing to their superior ride comfort and dust-free characteristics. The performance of asphalt pavements primarily depends on their key component - the asphalt mixture. Based on different construction techniques, asphalt mixtures can be classified into two main categories: hot mix asphalt (HMA) and warm mix asphalt (WMA). Compared with hot mix asphalt (HMA), warm mix asphalt (WMA) is produced at approximately 30°C lower temperatures. This significant reduction in construction temperature substantially decreases the emission of asphalt fumes, carbon dioxide, and other hazardous gases during mixing and compaction processes. Consequently, WMA technology mitigates adverse impacts on both construction workers' health and the surrounding environment.

Generally, warm mix asphalt (WMA) technology can be classified into three main categories: surface-active warm mix technology, organic additive technology, and foamed asphalt technology. Among these, foamed asphalt technology stands out due to its cost-effectiveness. Specifically, producing one tonne of foamed WMA mixture consumes 1–1.5 kg less fuel compared to conventional hot mix asphalt (HMA), significantly enhancing energy efficiency. Owing to these advantages, foamed warm mix asphalt has gained widespread application in practice[1-3].

Extensive engineering practice and research have demonstrated that while warm mix foamed asphalt offers significant advantages, its water stability performance requires further improvement[4-6].

In China's northeast monsoon freezing region, characterized by high summer temperatures, extremely low winter temperatures, and heavy snowfall, accumulated snow significantly impacts road traffic. To maintain traffic flow during winter months, snow-melting salts are commonly applied to road surfaces. However, under these unique environmental conditions, asphalt pavements suffer severe deterioration from combined salt erosion and water damage, primarily exhibiting surface raveling, pothole formation, and cracking. These distresses substantially reduce pavement service life and compromise traffic safety. Particularly concerning is freeze-thaw cycling, which exacerbates moisture damage and has become a major constraint for foamed asphalt mixture applications in this climate zone. Consequently, enhancing water resistance through asphalt modification has emerged as a critical research focus for improving the performance of foamed asphalt mixtures in these challenging conditions

Silane coupling agent as a commonly used modifier to improve the bonding between materials[7-10]. In order to evaluate the effect of silane coupling agents on the water stability of foamed asphalt mixtures, In this paper, split tests were conducted to investigate the water stability of matrix asphalt (AH90) mixes, foamed asphalt (FAH90) mixes and silane coupling agent modified foamed asphalt (MFAH90) mixes after salt-freeze-thaw cycles. 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

(1) Asphalt

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

(2) Packing material

The coarse aggregate used is pyrophyllite produced by Weifeng quarry, the material is clean and free of impurities. The fine aggregate is mechanism sand produced by Weifeng quarry, the material is clean and free of impurities. Mineral powder is limestone mineral powder produced by Yida Mining, the material is dry and free of lumps.

2.2. Method

In this paper, three different asphalt mixtures are prepared for water stability studies after salt-freeze-thaw cycles, namely AH90 mix, FAH90 mix and MFAH90 mix. The split test specimen is a specimen with a diameter of $101.6 \text{ mm} \pm 0.25 \text{ mm}$ and a height of $63.5 \text{ mm} \pm 1.3 \text{ mm}$ moulded by the Marshall standard compaction method. The Marshall specimens are shown in Fig.1.



Fig 1. Marshall specimens

In order to simulate the environmental characteristics of winter pavements subjected to salt solution erosion in the monsoon freezing zone, AH90 mixes, FAH90 mixes and MFAH90 mixes were subjected to 0, 5, 15, and 30 salt-freeze-thaw cycles, and the test equipment was a household refrigerator, as shown in Figure 2-3.



Fig 2. Test Refrigerator

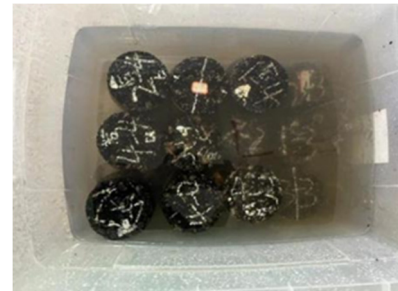


Fig 3. Soaking in snow-melting salt water solution

(1) Splitting test

This paper is based on the splitting test of asphalt mixtures in the *Test Procedure for Asphalt and Asphalt Mixtures in Highway Engineering (JTG E20-2011)*. Splitting tests were carried out on AH90 mix, FAH90 mix and MFAH90 mix after 0, 5, 15 and 30 salt-freeze-thaw cycles, and the strength ratios of splitting damage were calculated to evaluate the water stability of silane coupling agent modified foam asphalt mixtures. The test temperature was 25°C and the loading rate was 50 mm/min .

3. Result

The split tensile strength ratios of various types of asphalt mixtures after different salt-freeze-thaw cycles were calculated from the salt-freeze-thaw split test and are shown in Table 2.

Table 2. Split tensile strength ratio of various types of asphalt mixtures after different salt-freeze-thaw cycles

Type of mix	5 times	15 times	30 times
AH90	86.3%	79.2%	75.2%
FAH90	83.7%	77.2%	68.3%
MFAH90	88.0%	83.5%	78.6%

From Table 2 , the split tensile strength ratios of asphalt mixtures after salt-freeze-thaw cycles were comparatively analysed and the following conclusions were drawn:

(1) With the increase in the number of salt-freeze-thaw cycles, the split tensile strength ratio of all types of asphalt mixtures gradually decreased, and the water stability of asphalt mixtures decreased.

(2) The salt thaw split strength ratio of the MFAH90 mix increased by 4.3% after 5 freeze-thaw cycles compared to the FAH90 mix. After 15 freeze-thaw cycles, the salt thaw splitting strength ratio of MFAH90 mixes increased by 6.3%. After 30 freeze-thaw cycles, the salt thaw split tensile strength ratio of MFAH90 mixes increased by 10.3%. It indicates that the water stability of the silane coupling agent modified foamed asphalt mixture is greatly improved.

(3) The salt freeze-thaw split strength ratio of the MFAH90 mix exceeded the salt freeze-thaw split tensile strength ratio of the AH90 mix, indicating that the addition of the silane coupling agent improved the water stability of the foam asphalt mix and compensated for the lack of water stability of the foam asphalt mix.

(4)The water stability of various types of asphalt mixtures, in descending order, is as follows: MFAH90 mixture > AH90 asphalt mixture > FAH90 mixture.

4. Conclusion

In order to evaluate the effect of silane coupling agents on the water stability of foamed asphalt mixtures, In this paper, split tests were conducted to investigate the water stability of matrix asphalt (AH90) mixes, foamed asphalt (FAH90) mixes and silane coupling agent modified foamed asphalt (MFAH90) mixes after salt-freeze-thaw cycles. The following conclusions were drawn.

(1)With the increase in the number of salt-freeze-thaw cycles, the split tensile strength ratio of all types of asphalt mixtures gradually decreased, and the water stability of asphalt mixtures decreased.

(2)the addition of the silane coupling agent improved the water stability of the foam asphalt mix and compensated for the lack of water stability of the foam asphalt mix.

(3) The water stability of various types of asphalt mixtures, in descending order, is as follows: MFAH90 mixture > AH90 asphalt mixture > FAH90 mixture.

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