Study on Laboratory Experimental Pavement Performances of SEAM Modified Asphalt Mixture

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Abstract: Adding sulphur dilution asphalt modifier SEAM to asphalt mixture is not only a modifier of asphalt mixture, but also an additive of asphalt mixture. When the modifier is added into the asphalt mixture, the road performance of the asphalt mixture can be improved. This paper studies SEAM modified asphalt mixture the Marshall property index, temperature stability, Water stability and fatigue feature in the Laboratory. On the based of the result of the experiment and analysis, SEAM can improve the high temperature stability, Water stability and fatigue feature. But the low temperature stability can't improve.

1 Introduction

It has been a long time since asphalt was modified, and it is generally modified by adding additives such as polymer, surfactant and anti-aging agent. As early as 1873, Samuel Whiting of the United Kingdom applied for a patent for rubber modified asphalt [1], and in 1902, France constructed asphalt pavement mixed with rubber [2]. Up to now, there are more than 100 kinds of modified asphalt. Novophalt, Shell, Esso, Koch, caltex and other well-known brands have developed mature modified asphalt processing technology and modified asphalt products.

The study of modified asphalt began in China after 1980s. There are many kinds of asphalt modifiers, but different modifiers have their inherent characteristics. Through research and application, the variety and quantity of modifiers are changing constantly. At present, all kinds of polymers are mainly used to achieve results and form a scale, while other types are not widely used [3]. In heavy traffic, the overload transportation common cases in China, while some used modified asphalt on pavement surface, but there is still a serious early damage. The reason is the poor of the high temperature stability of the middle and bottom layer. In this case, many experts claim: the bottom layer is also used in these sections of modified asphalt, but it will lead to too much money problems, application of SEAM asphalt mixture can alleviate this contradiction. SEAM asphalt mixture can not only meet transportation needs but also with-out adding investment [4-7].

SEAM is a shortened name for Sulphur- Extended Asphalt Modifier, i.e. Sulphur dilution Asphalt Modifier. SEAM is a new type of asphalt modifier and also an additive of asphalt mixture. As early as the beginning of the 20th century, it was found that adding sulfur to asphalt mixture can improve the physical structure and

mechanical properties of the mixture. But in the early 1980s, there was a global shortage of sulfur, and prices skyrocketed. There was a time when the use of sulfur modified asphalt was discontinued. With the progress of society and the development of science and technology, the fuel desulfurization of oil refineries and the extremely high sulfur output from sulfur containing natural gas and oil sands, the price of sulfur will continue to fall, while the price of oil remains high, which promotes the price of asphalt. As a result, alternatives to asphalt have been sought. In the early 1980s, Rockbond corporation of the United States developed SEAM particles by adding a smoke inhibitor to sulfur. China to SEAM asphalt application relatively late, the research on study of sulfur in the asphalt pavement is less, contact the sulfur is used in the asphalt surface in China begin of shell company of Canada in 2001 invented the new SEAM materials [8]. In the same year, China built the SEAM modified asphalt test road in Tianjin [9], then also built test road in Hei Long-jiang [10], and achieved good results, but overall application on a smaller scale, research is not systematic and comprehensive. In view of the serious rutting and poor high-temperature stability of highway asphalt pavement, this paper systematically and comprehensively studies the road performance of sulfur modified asphalt mixture, and the research results have certain theoretical and application value for the popularization and application of SEAM modified asphalt mixture.

2 Selection and test of raw materials

Coarse, fine aggregate are limestone stone, ore fines for grinding limestone powder. Coarse aggregate and fine aggregate are all limestone stone produced by Zhenjiang MouTi stone co, LTD of China, and the filler is mineral powder produced by Nanjing Tangshan mineral powder co., LTD of China. Asphalt is the road oil bitumen of

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SK-70 # in South Korea. The technical indexes of bitumen are shown in table 1. SEAM is a SEAM modifier produced by Bei Jing Li An-long company of China.

Table 1. Technical specifications of bitumen

Bitumen	Penetration (25°C, 100g, 5s(mm))	Softening point (ring and ball method) (°C)	Ductility (15°C, 5cm/min(cm))
SK-70 # in South Korea	68.0	50.0	>100

SEAM is a particle made by adding smoke inhibitor and plasticizer components to sulfur. The asphalt surface layer with rigid, semi-rigid, flexible and other properties can be obtained by changing SEAM's mixing amount. When SEAM: bitumen is equal to 50:50, you can get a very hard rigid mixture, according to the volume ratio, SEAM replaces about 40% of the bitumen. This surface material has excellent anti-rutting performance, but its flexibility is very low, which is good for subgrade. At the same time, due to the high SEAM content, the hardening of the mixture after spreading is relatively early, so it must be operated quickly to quickly reach the required compaction density at no less than 110°C. When SEAM: bitumen is equal to 40:60, you can get a semi-rigid mixture which can replace about 30% bitumen. The stability of the mixture is higher than that of the conventional asphalt mixture, so the paved road has higher rutting resistance, and at the same time can maintain enough flexibility and better fatigue resistance. When SEAM: bitumen is equal to 30:70, you get a "flexible" mixture, which can replace about 20% of the bitumen. The performance of this mixture is basically similar to that of conventional asphalt mixture, and the strength and stability of this mixture are slightly better than that of ordinary asphalt mixture, which can also meet the service performance. In view of the heavy traffic in China, this test is intended to use SEAM: bitumen is equal to 40:60, SEAM: bitumen is equal to 30:70 to form SEAM modified asphalt concrete for the test.

3 Test scheme design and parameter determination

3.1 Aggregate grading

In this test, the asphalt mixture type is AC-20C, and the aggregate synthesis grading determined by the test is shown in figure 1.

Figure 1. Synthetic grading diagram of bitumen mixture ore

3.2 Design of test scheme

In this test, SEAM is used as the modifier of asphalt mixture, and modified asphalt mixture is prepared according to two kinds of admixtures (SEAM: bitumen = 30:70, SEAM: bitumen = 40:60). SEAM: bitumen = 30:70 and SEAM: bitumen = 40:60 were used for comparative test. The gradation type of asphalt mixture is AC-20C dense asphalt mixture. Asphalt mixture test includes Marshall test, rutting test, low temperature splitting test, low temperature bending test, immersion Marshall test, splitting freeze-thaw test, splitting fatigue and trabecular bending fatigue test. The improvement effect of SEAM on road performance of asphalt mixture is evaluated through the analysis of test results.

The flow chart of the test scheme is shown in figure 2.

Figure 2. Flow chart of test scheme

3.3 SEAM asphalt mixture mix design

Marshall test method is adopted to determine the optimal amount of SEAM and bitumen in SEAM modified asphalt mixture. The design steps are as follows:

1.Marshall mixture design method is adopted to conduct Marshall test on the asphalt mixture without SEAM modification, so as to obtain its optimal oil-stone

ratio (i.e. the ratio of the total weight of asphalt and mineral in the asphalt mixture).

2.Convert the obtained optimal oil-stone ratio into the asphalt content A and the initial quality ratio between SEAM and bitumen, calculate the SEAM quality fraction PS, and substitute it into equation (1) to obtain the quality fraction of SEAM modified asphalt, namely:

$$(SEAM + bitumen)\% = \frac{10000AR}{10000R - 100P_S(R - 1) + AP_S(R - 1)} \quad (1)$$

Among them: A--bitumen content in conventional mixture design

R--SEAM substitution coefficient (empirical recommendation 1.7)

P_S--Percentage of SEAM weight in total binder

3.Make Marshall specimen according to SEAM, bitumen content and designed aggregate gradation, test its Marshall stability and other indicators, and observe

whether it meets the requirements of strength and other aspects.

4.Adjust the quality ratio between SEAM and bitumen, repeat step (3) until the requirements of mixture strength and other aspects are met. At this time, the content of SEAM and bitumen obtained is the best proportion of SEAM modified asphalt mixture.

The combinations of various asphalt mixtures obtained in this study are shown in table 2~ table 4.

Table 2. Mix proportion of ordinary asphalt concrete

Optimum ratio of oil to stone (%)	Amount of various ore materials (%)				
	1# material	2# material	3# material	4# material	ore fines
4.3	36	25	4	32	3

Table 3. SEAM: bitumen =40: 60 mix ratio of modified asphalt concrete

SEAM proportion (%)	bitumen proportion (%)	Amount of various ore materials (%)				
		1# material	2# material	3# material	4# material	ore fines
1.96	2.94	36	25	4	32	3

Table 4. SEAM: bitumen =30: 70 mix ratio of modified asphalt concrete

SEAM proportion (%)	bitumen proportion (%)	Amount of various ore materials (%)				
		1# material	2# material	3# material	4# material	ore fines

1.40	3.27	36	25	4	32	3
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3.4 Road performance index of asphalt mixture

3.4.1 High temperature stability

Dynamic stability of rutting test according to the test regulations of highway engineering asphalt and asphalt mixture [11] (JTG E20-2011) was used to evaluate the high-temperature stability of common and SEAM modified asphalt mixtures. The strength of SEAM modified asphalt mixture will increase with time and increase steadily after 8 days. Therefore, the stability indexes of various asphalt mixtures at 1 and 8 days were compared.

3.4.2 Low temperature cracking resistance

This test used low-temperature bending test to evaluate the low-temperature cracking resistance of common and SEAM modified asphalt mixtures. The purpose of the test was to evaluate the low-temperature performance of asphalt mixture. Specimen were made in accordance with the test regulations of highway engineering asphalt and asphalt mixture (JTG E20-2011).

3.4.3 Water stability

The splitting strength ratio of freeze-thaw splitting test was used to evaluate the water damage resistance of common and SEAM modified asphalt mixtures.

3.4.4 Fatigue performance

According to the feasibility of the test and the current test conditions, a simple splitting fatigue test was adopted to evaluate the fatigue performance of asphalt mixture. For the test temperature, according to the relevant research results, the fatigue damage of asphalt mixture was mainly concentrated in 13 ~15°C, which corresponded to the temperature of the spring melt period in northern China and the rainy season in southern China. Generally, 15°C is considered as the most unfavorable situation, and the allowable tensile stress index in the design code of Chinese asphalt pavement is also a parameter value of 15°C. At the same time, the difference of temperature will also cause the change of modulus of asphalt mixture, which directly affects its fatigue life. Therefore, 15°C is selected as the test temperature and the stress control mode is adopted for the test. As for the loading wave type, a large number of studies believe that the moving wheel load has a stress-strain effect close to the sinusoidal curve on the road surface. Therefore, sinusoidal loading wave type is adopted with the load frequency of 10HZ.

4 Road performance test results and analysis

4.1 High temperature stability

In this test, dynamic stability of rutting test according to the test regulations of highway engineering asphalt and asphalt mixture (JTG E20-2011) was used to evaluate the high-temperature stability of various asphalt mixtures. The experimental result is shown in figure 3.

Figure 3. Comparison diagram of dynamic stability

As can be seen from figure 3, the dynamic stability of asphalt mixture is greatly improved after SEAM is added. For SEAM: bitumen = 30:70 modified asphalt mixture, the 1-day dynamic stability is increased by 51.0% compared with ordinary asphalt mixture. For SEAM: bitumen = 40:60 modified asphalt mixture, the 1-day dynamic stability was increased by 144.0% compared with normal asphalt mixture. With the increase of time, the dynamic stability of ordinary asphalt mixture increased only 18.8% within 8 days. SEAM: bitumen = 30:70 modified bitumen mixture, up 47.3%; SEAM: bitumen = 40:60 modified asphalt mixture, increased by 54.6%. As can be seen from the test results, with the increase of SEAM admixture, the dynamic stability increases greatly, and with the increase of time, the dynamic stability increases with the increase of modifier admixture.

According to the analysis of the high-temperature stability test results of the asphalt mixture, SEAM admixture can greatly improve the high-temperature stability of the asphalt mixture, and with the increase of time and SEAM admixture, the strength of SEAM modified asphalt mixture also increases.

4.2 Low temperature cracking resistance

In this test, the main evaluation index is failure bending strain obtained from bending test to evaluate the low temperature crack resistance of common and SEAM modified asphalt mixtures. The experimental result is shown in figure 4.

Figure 4. Comparison diagram of failure bending strain

As can be seen from figure 4, SEAM (40:60) modified asphalt mixture is the best when the maximum bending strain is taken as the evaluation index. The order is: SEAM (40:60) modified asphalt mixture is superior to SEAM (30:70) modified asphalt mixture, and SEAM (30:70) modified asphalt mixture is superior to ordinary asphalt mixture. The test results show that SEAM can improve the performance of asphalt mixture at low temperature.

4.3 Water stability

The splitting strength ratio of freeze-thaw splitting test was used to evaluate the water damage resistance of common and SEAM modified asphalt mixtures. The experimental result is shown in Figure 5.

Figure 5. Comparison of splitting strength

It can be seen from the test result in Figure 5 that the splitting strength ratio of ordinary asphalt concrete with SEAM is certain to be improved. For SEAM: bitumen = 30:70 modified asphalt mixture, the splitting strength is increased by 4.9% compared with ordinary asphalt mixture. For SEAM: bitumen = 40:60 modified asphalt mixture, the splitting strength increased by 6.9% compared with that of ordinary asphalt mixture. It is concluded that the water stability of asphalt mixture is improved after SEAM is added, and the water stability is also improved with the increase of SEAM content.

4.4 Fatigue performance

In this study, the laboratory test method is mainly used, and the simple and easy splitting fatigue test was adopted. The experimental results are shown in Figure 6.

Figure 6. Comparison of splitting fatigue life

As can be seen from the test results in figure 6, the fatigue performance of SEAM modified asphalt mixture has been greatly improved. The fatigue life of SEAM: bitumen = 30:70 modified asphalt mixture is about 1.5 times that of ordinary asphalt mixture, while SEAM: bitumen = 40:60 modified asphalt mixture is about twice that of ordinary asphalt mixture. It shows that SEAM's addition can greatly increase the ability of ordinary asphalt concrete to withstand repeated loads, and the fatigue life of ordinary asphalt concrete increases with the increase of mixing amount. The test result shows that SEAM modified asphalt mixture pavement can withstand more highway load.

5 Conclusion

Of all kinds of asphalt mixture rutting test, low-temperature bending test and freeze-thaw splitting test and splitting fatigue test results can be concluded that: adding SEAM modifier particles, it can improve the high temperature stability, water stability and fatigue resistance performance of asphalt mixture, and with the increase of dosage of SEAM, the performance of mixture has obvious improvement. However, the low temperature cracking resistance did not improve significantly.

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