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Study on Performance of Composite Flame-retardant Asphalt Material in Tunel

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Abstract. In order to study the pavement performance of flame-retardant asphalt mixture, firstly, three kinds of compound flame-retardant modified asphalt, 3%, 6% and 9%, were prepared by high speed shearing method. The optimum dosage of composite flame retardant material was selected through segregation test, oxygen index test and smoke density test. Secondly, the road performance of asphalt mixture was analyzed by rutting test, low temperature splitting test and freezing thawing splitting test system. The results show that when the dosage of flame-retardant composites is 6%, the segregation degree of SBS modified asphalt mixture is the minimum, and it can effectively improve the flame retardant effect and smoke suppression effect of SBS modified asphalt. The high temperature stability and the low temperature crack resistance of the 6% composite flame retardant asphalt mixture have been improved, while water stability has not been much affected.

1. Introduction

In recent years, with the rapid development of the highway in China, the emergence of tunnels is becoming more and more common in the road. At present, cement concrete is mainly used for tunnel pavement in China due to its waterproof and non-flammable characteristics. However, in order to improve the comfort of the tunnel pavement and consider the noise problem, we should consider the use of asphalt concrete pavement in the tunnel. But the asphalt pavement in the tunnel is easy to ignite and then release heat and harmful smoke, and make the disaster worse, so this is very important for improving the fire safety of the asphalt pavement in the tunnel [1-2]. The contribution of FR asphalt road to the Spanish fire growth was studied by the Cone Calorimeter and Fourier Transform Infrared Spectroscopy analyses [3-4]. Li Xuelian uses the flash point, oxygen index and combustion test of asphalt binder to understand the flame retardancy of bitumen and mixture [5]. Several researchers in China evaluated the influence of flame-retardant asphalt aging on pavement performance, and the composition design method of flame-retardant asphalt mixture [6-7]. At the same time, the effect of flame retardant on asphalt mixture road performance and combustion performance and the dynamic performance of flame retardant asphalt have also been studied by some researchers [8-9].

In conclusion, there are abundant researches on the application performance of flame retardant asphalt and asphalt mixture, but there is still a lack of research on smoke suppression effect of flame-retardant asphalt. The harmful gas caused by bitumen combustion is also an important factor in causing casualties during tunnel fires. The harmful gas caused by bitumen combustion is also an important factor in causing casualties during tunnel fires. Therefore, this paper studied the flame retardancy, smoke suppression performance, and composite flame retardant materials of the best blended flame-retardant asphalt through indoor testing methods. The compatibility of asphalt and the road performance of flame-retardant asphalt were studied. These studies will help the application of flame retardant asphalt mixture in tunnel engineering.

2. Materials and method

The diatomite used in the test is produced in Changbai County, Jilin province. The performance index of SBS modified asphalt shows as shown in Table 1 of the technical indicators. The main components of the compound flame retardant are aluminum hydroxide, ammonium polyphosphate and diatomite, as well as the corresponding flame retardant components. The test used the following method: segregation test, oxygen index test and smoke density test.

Table 1. Technical Indexes of SBS Modified Asphalt

Project	**Test Results**	**Skills Requirement**
Penetration（25℃，100g，5s）/ 10-1mm	74	60～80
Softening Point /℃	77.5	≥55
Ductility /cm	≥30	32
Kinematic viscosity（mm2/s）	2162	--

3. Results and discussion

3.1. Determination of the optimum content of composite flame retardant materials

3.1.1. Segregation test

By using the method of polymer modified asphalt segregation test in the asphalt mixture test regulation, the degree of segregation of flame retardant asphalt is evaluated by the penetration index. The results of the test are as follows.

Table 2. Penetration test penetration test results

Content of composite flame retardant materials（%）	**Penetration（0.1mm）**		**Penetration difference（0.1mm）**
	Upper part mean	**Lower part mean**	
3	77.0	76.8	0.2
6	79.6	78.6	1
9	80.0	77.4	2.6

According to Table 2, when the content of the composite fire-retardant material is 3%, the penetration of the upper and lower parts of the asphalt does not change significantly, indicating that when the content of the composite fire-retardant material is small, the composite fire-retardant material and asphalt has good compatibility and no obvious segregation will occur. When the content of the composite flame retardant was 6%, although the difference between the penetration of the upper portion and the lower portion was changed, the overall was not obvious, and no serious segregation phenomenon occurred. However, when the blending amount was 9%, the penetrability changed significantly and the segregation phenomenon was obvious. Therefore, the optimum content of composite fire-retardant materials is 3% and 6%.

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3.1.2. Oxygen index test.

Oxygen index is an indicator that quantitatively describes the continuous combustion performance of a polymer. The flame retardant performance of asphalt was evaluated using the limiting oxygen index. The limiting oxygen index is the lowest concentration of oxygen required to maintain stable combustion in a mixed stream of oxygen and nitrogen under the specified test conditions. And the higher the limiting oxygen index, the more difficult it is to burn the material. The test results are shown in Figures 1.

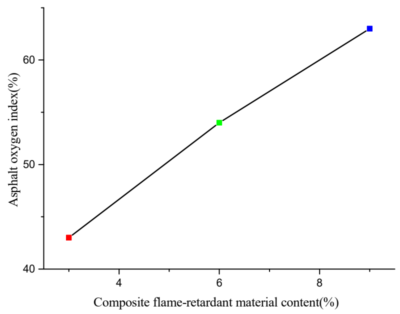

Figure 1. Relationship Between the Content of Composite Flame-retardant Material and the Limiting Oxygen Index of Asphalt

From Figures 1, it can be seen that as the content of the composite flame retardant material increases, and the limiting oxygen index also increases, and the limiting oxygen index increases compared to when the composite flame retardant material is not added. Therefore, the incorporation of composite flame retardant material can effectively improve the flame retardant effect of asphalt.

3.1.3. Smoke density test.

The smoke density method is defined as the smoke produced by burning a test piece of a prescribed volume in a prescribed volume of the smoke box, measuring the change of the transmittance of the parallel light beam passing through the unit light path in the smoke, and calculating the specific light density. The test of asphalt smoke density is quite different from other materials, because asphalt needs to be burned under certain temperature conditions, so for this particular problem, the asphalt should be preheated on the electric furnace before testing, and then the preheated asphalt was transferred to a cigarette box for testing, using three sets of parallel test pieces. The specific test results are shown in Figures 2.

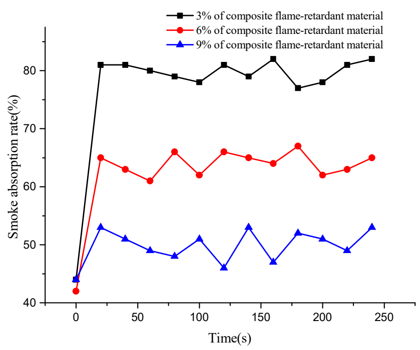

Figure 2. SBS Modified Asphalt Smoke Density Curve with Composite Flame-retardant Material.

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From Figures 2, when 3% of the composite flame retardant material is added, the smoke absorption rate when bitumen is burned does not increase significantly, still about 80%. When 6% of the composite flame-retardant material is added, the smoke absorption rate when the asphalt is burned is significantly reduced, which is about 65%; When 9% of the composite flame-retardant material is added, the smoke absorption rate when the asphalt is burned is further reduced to about 50%. Therefore, the incorporation of the composite flame-retardant material can effectively improve the effect of the asphalt in suppressing smoke generation.

To sum up, considering the segregation degree of SBS modified asphalt and composite flame retardant materials, the oxygen index and smoke density of flame retardant asphalt, and considering the economy of material consumption, the optimum content of composite flame retardant material is 6%.

3.2. Road performance of composite flame-retardant asphalt mixture

3.2.1. High temperature stability.

The dynamic stability index of the rutting test was used to evaluate the high temperature stability of the flame-retardant asphalt mixture. Six sets of parallel test pieces were used. The test results are shown in Table 3.

Table 3. Asphalt Mixture Rutting Test Results

Mixture type	**Dynamic Stability Mean DS（Times /mm）**
SBS modified asphalt mixture	5345
Flame-retardant asphalt mixture	5498

According to Table 3, when adding 6% composite flame retardant material, the dynamic stability of asphalt mixture increased by 2.9%, indicating that the addition of composite flame retardant did not reduce the high temperature stability of SBS modified asphalt, but increased slightly. Therefore, the addition of composite flame retardants did not affect the high temperature stability of SBS modified asphalt.

3.2.2. Low temperature crack resistance performance.

The low-temperature cracking resistance of the flame-retardant asphalt mixture was evaluated by the splitting strength index and the ultimate breaking strength and strain of the low-temperature splitting test and the low-temperature trabecular bending test. The test results are shown in Figure 3 and 4.

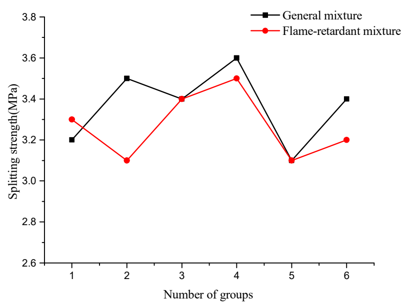

Figure 3. Low Temperature Splitting Strength of Asphalt Mixture

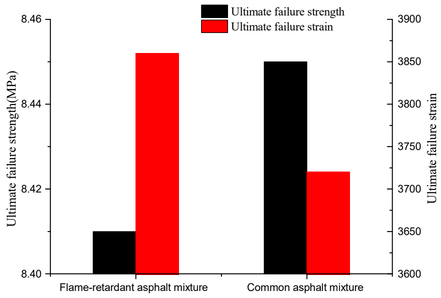

Figure 4. Ultimate Failure Strength and Strain of Asphalt Mixture

Figure 3 shows that when the composite flame retardant material is added to the SBS modified asphalt, the low temperature splitting strength of the asphalt mixture does not decrease, indicating that the low temperature performance of the flame retardant asphalt mixture is not reduced. On the other hand, Figure 4 shows that after the addition of the composite flame retardant material, the ultimate bending failure strength of the asphalt mixture is reduced, while the ultimate bending failure strain is increased. However, the ultimate bending failure strain has been increased, but in the two indicators of ultimate bending failure strength and strain, ultimate bending failure strain can more reflect the low temperature performance of the material. Based on the experimental results of the two tests, it can be seen that the low-temperature performance of the SBS modified asphalt added with the composite flame-retardant material has not been affected, but has been improved.

3.2.3. Water stability.

The splitting tensile strength ratio of the freeze-thaw splitting test was used to evaluate the water stability of the flame-retardant asphalt mixture. Six sets of parallel test pieces were used. The test results are shown in Figure 5.

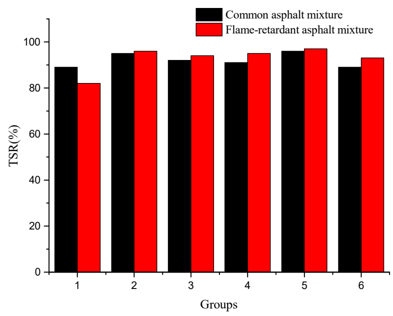

Figure 5. Mixture Freeze-thaw Splitting Test Results

From Figure 5, it is known that the TSR value of asphalt mixture with composite flame retardants is approximately the same as that of SBS modified asphalt mixture. Therefore, the water stability of SBS modified asphalt has not been affected by the addition of composite flame retardant.

4. Conclusion

Through the oxygen index and the smoke density and the compatibility of the asphalt and the composite flame-retardant material, the optimal blending amount of the composite flame-retardant material was finally determined to be 6%, considering the economic applicability. The composite flame retardant improves the turbulence stability of the asphalt mixture, demonstrating that the high temperature performance of the flame retardant asphalt mixture is improved. The ultimate bending failure strength of the SBS modified asphalt is slightly reduced, but the ultimate bending failure strain of the asphalt is improved, and the low temperature splitting strength of the asphalt mixture is not reduced, which indicates that the low temperature performance of the asphalt mixture is improved. TSR value of the asphalt mixture remains basically unchanged and does not affect the water stability of the asphalt mixture. The use of composite flame-retardant materials not only can effectively improve the flame-retardant effect and smoke suppression effect of bituminous materials, but also has good compatibility with asphalt and low manufacturing cost. It can be applied to tunnel asphalt pavement very well and has broad application prospects.

Acknowledgments

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