International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Environmental and Earth Sciences Research Journal
Vol. 9, No. 2, June, 2022, pp. 74-78
Journal homepage: http://iieta.org/journals/eesrj

An Active Anti-Aging Technology for Asphalt Mixture

Zhi Lin[1], Baoxiang Liu[2], Zhou Qiu[3], Chuanfeng Zheng[4*], Haisong Luo[1], Wenyue Liu[1]

[1] College of Construction Engineering, Jilin University, Changchun 130061, China
[2] Haiwei Engineering Construction Co., Ltd of FHEC of CCCC, Beijing 101119, China
[3] CCCC Third Highway Engineering Co., Ltd., Beijing 100011, China
[4] School of Transportation, Jilin University, Changchun 130022, China

Corresponding Author Email: cfzheng@jlu.edu.cn

https://doi.org/10.18280/eesrj.090208

Received: 28 March 2022
Accepted: 21 May 2022

Keywords:
anti-aging, asphalt light component, oil shale wastes, asphalt mixture, grading design

ABSTRACT

For aged asphalt, as the content of light component gets smaller with the passing of time, the performance of the asphalt mixture would degrade accordingly. This study aims to develop an anti-aging material that can supplement light component to asphalt pavement during its service process, thereby suppressing the aging of asphalt and prolong the service life of the road surface. At first, this study carried out four-component separation test to measure the loss mass of light component; then in the experiment, the oil shale wastes were impregnated in light component to determine its adsorption capacity to the light component. After that, according to the loss of asphalt light component after long-term aging and the adsorption ratio of anti-aging materials with different particle sizes for light component, the amount of anti-aging material to be added was determined; moreover, via rutting test, beam bending test, and freeze-thaw splitting test, the high-temperature stability, low-temperature crack resistance, and water stability of the asphalt mixture modified by the proposed anti-aging material had been verified, and the results proved that the proposed anti-aging material can well suppress the aging of asphalt mixture.

1. INTRODUCTION

Oxygen, sunlight, temperature, moisture, and other factors can cause asphalt aging during its service as road pavement [1-5], which can severely degrade the performance of the asphalt pavement and greatly shorten its service life. In such case, special treatment measures are required to suppress the aging of asphalt pavement, so developing anti-aging materials is very meaningful for improving the performance of asphalt pavement and prolonging its service life [6-10].

Physical and chemical reactions such as oxidation, volatilization, and polymerization can all cause the asphalt to age [11-13], but essentially, the common mechanism is the reduction of light component in asphalt. At present, there're mainly two types of anti-aging treatment measures, one is to add anti-aging materials, such as antioxidants, controlled release agents, and UV absorber; the other is to treat modifiers with processes such as intensified distillation, epoxy oil impregnation, and microwave irradiation [14, 15].

The idea of this paper is not to prevent the volatilization of light component in the asphalt, but to supplement light component to the asphalt during its service, so as to balance the light component and slow down the aging process of asphalt. The objective of the experiment is to store the light component in the carrier material and use it to replace a certain amount of aggregates with the same particle size, and then use the new material to prepare the asphalt mixture, thus, it's necessary to choose the right carrier material and the light component supplement material in the experiment.

After kerogen has been extracted from oil shale, a lot of wastes would be left, in which a large number of microscopic pores could be observed under the action of high temperature, and it is a good option for carrier material. China has rich oil shale reserves, each year, a large amount of oil shale wastes would be produced, which can ensure the supply of such carrier material.

In this study, the oil shale wastes were impregnated in light component, then the wastes adsorbed with light component were taken as the anti-aging material and used to replace a certain amount of aggregates with the same particle size. Then, the light component adsorbed in the wastes released slowly in the aged asphalt to supplement light component for it, thereby suppressing its aging. After that, the basic properties of the asphalt mixture before and after aging were tested to verify the effect of the anti-aging material, in the purpose of providing a new method for suppressing asphalt aging.

2. TEST MATERIALS AND METHODS

2.1 Materials

Table 1. Basic properties of asphalt (Maoming 70#)

Asphalt	Penetration /0.1mm/25℃	Ductility /cm/5℃	Softening Point /℃	Standard Viscosity /(Pa.s)/60℃
Maoming 70#	68	55	45.7	141

The type of asphalt used in the experiment is Maoming 70#, its basic properties are listed in Table 1. The aggregate used in the experiment is basalt, and its basic properties are listed in Table 2. The oil shale wastes came from an oil shale waste storage area in Jilin Province of China, and the light component is diesel 5#.

Table 2. Basic properties of aggregate (basalt)

Test item	Test result	Technical requirement
Water absorption rate (%)	0.323	≤3
Bulk density	2.482	—
Apparent density	2.691	≥2.5
Content of needle-shaped particles (%)	10.8	≤15
Crushing value (%)	21.9	≤28

2.2 Methods

2.2.1 Long-term aging of asphalt

In this study, asphalt was subject to Thin Film Oven Test (TFOT) for short-term aging, the test was carried out in accordance with the *Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering* (JTG E20-2011) (hereinafter referred to as Standard Test Methods). After short-term aging, 50 ± 0.5g of the asphalt sample was weighed and placed on a sample tray, and then put into a pressure aging vessel, the air pressure was set to 2.1MPa±0.1MPa, the temperature was set to 105°C, and the time was set to 20h.

2.2.2 Determination of components in asphalt

This study adopted the four-component separation method mentioned in the Standard Test Methods in the experiment, asphalt and the aged asphalt obtained after the long-term aging test were subject to four-component separation, and the results showed that, after long-term aging, the content of asphalt component increased by 5.4%, the gum component increased by 6.9%, the aromatic component decreased by 8.1%, the saturated component decreased by 4.2%, and the light component decreased by 12.3%. The obtained data are shown in Table 3.

Table 3. Content of asphalt components before and after asphalt aging (%)

	Asphalt component	Gum component	Aromatic component	Saturated component
Un-aged	31.85	6.23	49.21	12.71
Long-term aged	37.25	13.13	41.11	8.51

2.2.3 Determination of oil shale wastes' adsorption capacity for diesel

For the oil shale wastes, both particle size and porosity can affect the adsorption capacity; and for wastes produced in different places and processed by different methods, there're significant differences in their adsorption capacity for light component. In our experiment, at first, the oil shale wastes were crushed in a mixer, wastes of three particle sizes 1.18 mm, 0.6 mm and 0.3 mm were screened out; then, for each size, 150 g of crushed wastes were weighted and soaked in the light component to stand for 24 h. After that, the wastes absorbed with light component were filtered by a filter screen, their surface was dried, in this way, the anti-aging material had been attained, see Figure 1. Then, their mass values were weighted to get the adsorption ratio of light component adsorbed by oil shale wastes with different particle sizes, the data are given in Table 4.

Figure 1. Filtered oil shale wastes of three different particle sizes after soaked in diesel

Table 4. Adsorption ratio of light component adsorbed by oil shale wastes with different particle sizes

Mass (g)	Particle size (mm)	Mass of adsorbed diesel (g)	Adsorption ratio
150	1.18	29.1	0.19
150	0.6	44	0.29
150	0.3	55.6	0.37

2.2.4 Grading design of anti-aging asphalt mixture

In the experiment, at first, the content of anti-aging material added to the asphalt mixture was determined according to the loss mass of light component of the long-term aged asphalt and the adsorption ratio of anti-aging materials with different particle sizes for light component. Then, standard Marshall test pieces (mass of 1200g) mixed with the anti-aging material were prepared, based on a diesel-asphalt of 5%, the asphalt content of the first test piece was calculated to be 57.15g; also, according to the four-component separation test, after short-term aging, the light component loss of the asphalt was 12.3%, so for the 1200g asphalt mixture, after aging, the loss mass of light component was 7.03g. For the oil shale wastes with three particle sizes of 1.18mm, 0.6mm and 0.3mm, their respective adsorption ratio for light component was 0.19, 0.29 and 0.37. Taking the AC-16 gradation as an example, as shown in Table 5, the aggregate mass of three particle sizes of 1.18mm, 0.6mm and 0.3mm was 108.59g, 68.58g, and 45.72g, respectively; and the proportion of the three was 48.7%, 30.8% and 20.5%. In order to keep the total mass of asphalt mixture unchanged, with a same ratio, the anti-aging material of three particle sizes was used to replace a certain amount of aggregates of the same particle size, that is, the anti-aging material of 1.18mm particle size used 48.7%, the anti-aging material of 0.6mm particle size used 30.8%, and the anti-aging material of 1.18mm particle size used 20.5%. Therefore, to supplement 7.03g of light component, the used anti-aging material of particle size 1.18mm, 0.6mm, and 0.3mm was 21.42g, 9.61g, and 5.33g, respectively. In this paper, two gradation types AC-16 and SMA-16 were taken as control groups, according to the loss mass of light component, 60%, 80%, 100%, 120%, and 140% of light component was supplemented for them in the experiment, and the corresponding addition amount of anti-aging material for different light component supplement amounts was designed, as listed in Table 6.

Table 5. AC-16 and SMA-16 asphalt mixture

Mixture	Mass percentage (%) passing through the sieve mesh (mm)									
type	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	.075
AC-16	95	88	73	46	31	21.5	15.5	11.5	8.5	6
SMA-16	95	75	55	27	24	21	16	12	9	8

Table 6. Addition amount of anti-aging material in asphalt mixture (g)

Gradation type	Supplement amount of light component (%)	Particle size(mm) 1.18	0.6	0.3
AC-16	60	12.85	5.77	3.2
	80	17.14	7.67	4.26
	100	21.42	9.61	5.33
	120	25.7	11.53	6.4
	140	29.99	13.45	7.46
SMA-16	60	6.61	7.82	5.2
	80	8.82	10.42	6.93
	100	11.02	13.03	8.66
	120	13.22	15.64	10.39
	140	15.43	18.24	12.12

2.2.5 Basic properties of asphalt mixture before and after aging

For asphalt mixtures of different gradation types, according to the requirements stipulated in the *Technical Specifications for Construction of Highway Asphalt Pavements* (JTG F40-2004) (hereinafter referred to as the Specifications), asphalt mixture samples with and without the anti-aging material were prepared. The preparation method of aged asphalt mixture was: first, asphalt and aggregate were heated in a 165 °C oven for 4 hours, stirred every 1 hour, and then fabricated into test pieces according to the requirements of the Specifications, the attained short-term aged asphalt mixture was heated in a 85 °C oven for 120 hours, then the test pieces were taken out and cooled naturally to get the long-term aged asphalt mixture, which was then subject to the rutting test, beam bending test, and freeze-thaw splitting test respectively in the experiment.

3. RESULTS AND DISCUSSION

3.1 Effect of the active anti-aging material on high temperature stability

According to Figures 2 and 3, the addition of anti-aging material had no negative impact on the high-temperature stability of the asphalt mixtures of two types of gradation under un-aged state. Since the selected particle sizes of oil shale wastes were 1.18mm, 0.6mm, and 0.3mm, the large particle size aggregates acted as the skeleton, while the small particle size aggregates acted as the filler, and the added material only accounted for about 3% in the total mass of the asphalt mixture, so it had no impact on the performance of the asphalt mixture. After aging, due to the loss of light component or its conversion to other components, the asphalt mixture became harder and more brittle; the dynamic stability of AC16 mixture increased by 71%, after the anti-aging material had been added, it increased by 50~60.9%; as for the SMA16 mixture, its dynamic stability increased by 75.5%, after the anti-aging material had been added, it increased by 49.8~62.1%. After the aging of the mixtures of the two types of gradation, the changes of their dynamic stability both decreased with the increase of the supplement amount of light component. Before the supplement amount of light component reached 100%, the changes were faster, after the supplement amount reached 120%, the changes gradually tended to be stable. The reason was that a part of the anti-aging material volatilized during mixing and aging processes, so when the supplement amount of light component reached 140%, it was not much different from a supplement amount of 120%, indicating that the light component had reached saturation.

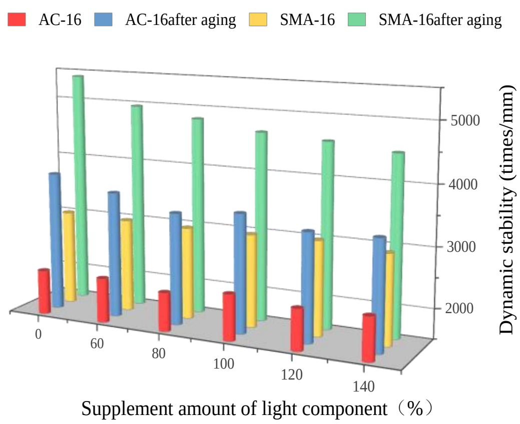

Figure 2. Dynamic stability of asphalt mixture before and after aging

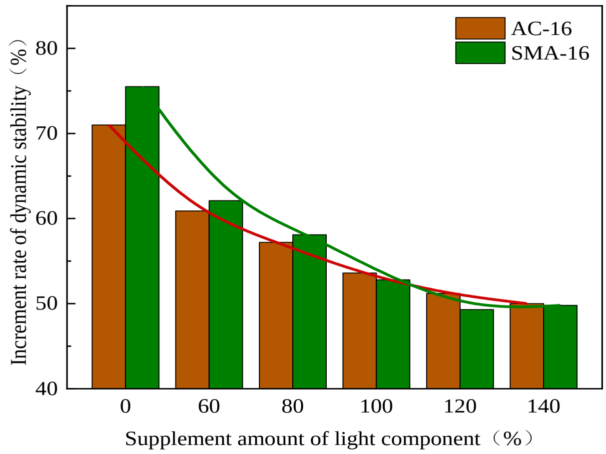

Figure 3. Increment rate of dynamic stability of asphalt mixture before and after aging

3.2 Effect of active anti-aging material on low-temperature crack resistance

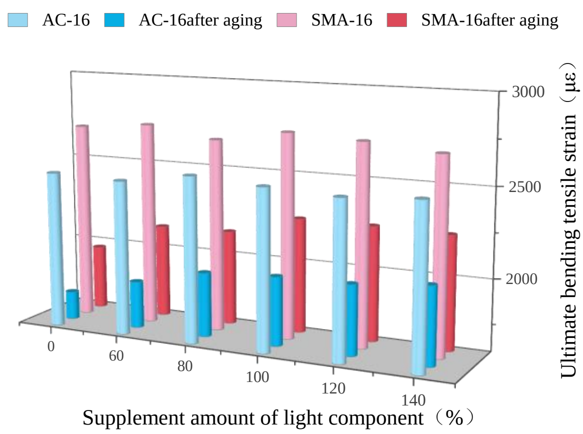

Figure 4. Ultimate bending tensile strain

As can be seen from Figures 4 and 5, the addition of anti-aging material had no negative impact on the low-temperature crack resistance of the asphalt mixtures of two types of gradation under un-aged state. After aging, the ultimate bending tensile strain of AC-16 mixture decreased by 29.2%, after the anti-aging material had been added, it decreased by 18.9-24.5%; as for the SMA-16 mixture, its ultimate bending tensile strain decreased by 27.6%, after the anti-aging material had been added, it decreased by 16.9~22.5%. For mixtures of the two types of gradation, after aging, both of their ultimate bending tensile strain decreased with the increase of the supplement amount of light component; the changes were faster when the supplement amount of light component was between 0 and 100%; while when the supplement amount was between 100% and 140%, the changes were gentler.

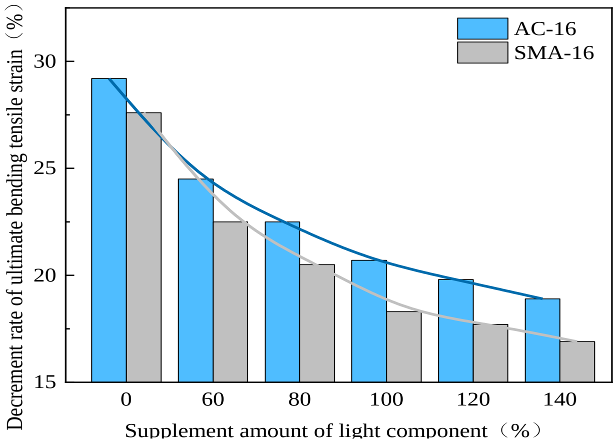

Figure 5. Decrement rate of ultimate bending tensile strain

3.3 Effect of active anti-aging material on water stability

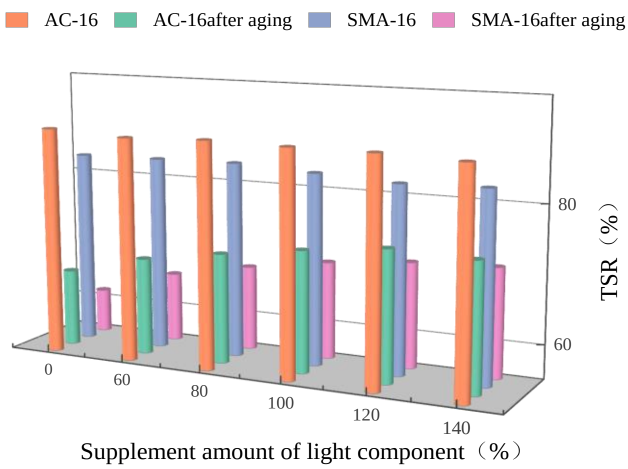

Figure 6. TSR

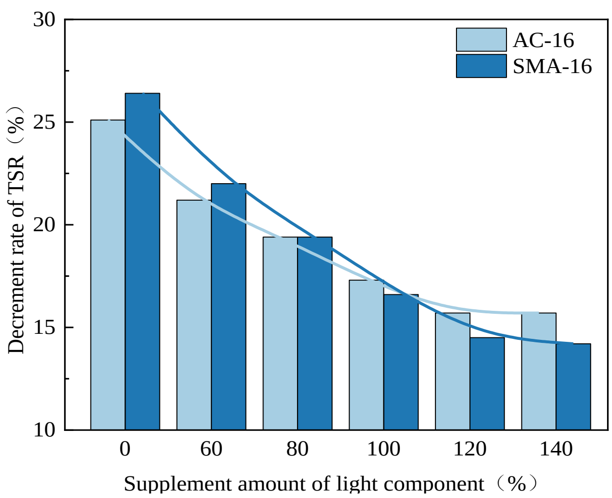

Figure 7. Decrement rate of TSR

As can be seen from Figure 6 and 7, the addition of anti-aging material had no negative impact on the water stability of the asphalt mixtures of two types of gradation under un-aged state. After aging, the TSR of AC-16 mixture decreased from 88.5% to 66.3%, the decrement was 25.1%, after the anti-aging material had been added, the decrement was 15.7-21.2%. As for the SMA-16 mixture, its TSR decreased from 83.4% to 61.4%, the decrement was 26.4%, after the anti-aging material had been added, the decrement was 14.2~22%. For mixtures of the two types of gradation, after aging, both of their TSR decreased with the increase of the supplement amount of light component, the changes were faster when the supplement amount of light component was between 0 and 120%; when the supplement amount was between 120% and 140%, the effect was basically the same.

4. CONCLUSION

This study conducted four-component test to measure the loss mass of light component after asphalt aging, designed addition amount of anti-aging material for different light component supplement amounts according to the oil shale wastes' adsorption capacity for light component, and performed rutting test, beam bending test, and freeze-thaw splitting test on asphalt mixtures before and after aging; after comparing the changes in the performance of the asphalt before and after aging, the effect of the anti-aging material had been verified, and follow conclusions were attained:

(1) The addition of anti-aging material had no negative impact on the high-temperature stability, low-temperature crack resistance, and water stability of the AC-16 mixture and the SMA-16 mixture under unaged state.

(2) The addition of anti-aging material had significant anti-aging effect on AC-16 mixture and SMA-16 mixture, the changes in their high-temperature stability, low-temperature crack resistance, and water stability became smaller obviously.

(3) With the increase in the addition of anti-aging material, the anti-aging effect improved fast when the supplement amount of light component was less than 120%; after the supplement amount reached 120%, the improvement of anti-aging effect slowed down, therefore, the optimal addition amount of the anti-aging material was 120% of the loss mass of light component in asphalt.

ACKNOWLEDGMENT

Science and Technology R & D project of China Communications Group (ZJLJ-2018-37).

REFERENCES

[1] Wang, W., Wang, Z., Guo, L. (2022). High-temperature property evaluation and index research of modified asphalt before and after aging. In Journal of Physics: Conference Series, 152(1): 012032.

[2] Zhang, W., Luan, Y., Ma, T., Wang, S., Chen, J., Li, J., Wu, M. (2021). Multilevel analysis of the aging mechanisms and performance evolution of rubber-modified asphalt. Journal of Materials in Civil Engineering, 33(12): 04021365.

[3] Byzyka, J., Rahman, M., Chamberlain, D.A. (2021). A

laboratory investigation on thermal properties of virgin and aged asphalt mixture. Construction and Building Materials, 305: 124757. https://doi.org/10.1016/j.conbuildmat.2021.124757
[4] An, S., Jo, Y., Park, T., Kim, K.W., Kim, S. (2022). Modeling of asphalt aging based on short-term aging temperature and time of normal asphalt mixture for quantifying binder aging. International Journal of Civil Engineering, 20(1): 15-25. https://doi.org/10.1007/s40999-021-00651-7
[5] Li, F., Yang, Y. (2021). The interfacial effect of mineral filler to asphalt binder and its influence on asphalt aging behavior. Materials and Structures, 54(1): 1-15. https://doi.org/10.1617/s11527-020-01605-6
[6] Xing, C., Liu, L., Sheng, J. (2020). A new progressed mastic aging method and effect of fillers on SBS modified bitumen aging. Construction and Building Materials, 238: 117732. https://doi.org/10.1016/j.conbuildmat.2019.117732
[7] Feng, Z.G., Cai, F.J., Yao, D.D., Li, X.J. (2020). FM analysis of aging properties of UV531/SBS modified bitumen. In IOP Conference Series: Materials Science and Engineering, 758(1): 012068.
[8] Lv, S., Peng, X., Liu, C., Qu, F., Zhu, X., Tian, W., Zheng, J. (2020). Aging resistance evaluation of asphalt modified by Buton-rock asphalt and bio-oil based on the rheological and microscopic characteristics. Journal of Cleaner Production, 257: 120589. https://doi.org/10.1016/j.jclepro.2020.120589
[9] Han, S., Zhang, Z., Zhang, Y., Cheng, X., Ren, W. (2019). Changes in rheological properties during asphalt aging. Petroleum Science and Technology, 37(13): 1539-1547. https://doi.org/10.1080/10916466.2019.1587454
[10] Rahmani, H., Shirmohammadi, H., Hamedi, G.H. (2018). Effect of asphalt binder aging on thermodynamic parameters and its relationship with moisture sensitivity of asphalt mixes. Journal of Materials in Civil Engineering, 30(11): 04018278. https://doi.org/10.1061/(ASCE)MT.1943-5533.0002453
[11] Zhang, W., Bahadori, A., Shen, S., Wu, S., Muhunthan, B., Mohammad, L. (2018). Comparison of laboratory and field asphalt aging for polymer-modified and warm-mix asphalt binders. Journal of Materials in Civil Engineering, 30(7): 04018150.
[12] Xie, X., Li, H., Duan, J., Li, G., Tong, S. (2020). Influence of the mineral powder content on the asphalt aging resistance in high-altitude areas based on indoor ultraviolet light tests. Materials, 13(3): 754. https://doi.org/10.3390/ma13030754
[13] Li, R. (2016). The study of asphalt mixture anti-aging performance study. International Journal of Intelligent Information and Management Science, 5(3): 111-115.
[14] Islam, M.R., Tarefder, R.A. (2015). Study of asphalt aging through beam fatigue test. Transportation Research Record, 2505(1): 115-120. https://doi.org/10.3141/2505-15
[15] Fang, C.Q., Zhang, M., Hu, J.B., Zhang, Y., Yu, R. E. (2011). Research progress on aging of polymer modified asphalt. Applied Mechanics and Materials, 71: 5038-5041. https://doi.org/10.4028/www.scientific.net/AMM.71-78.5038