

Research Article

Analysis of Natural Aging Behavior of Asphalt Binder in Cold and Arid Region

Shanglin Song,^{1,2,3} Meichen Liang,⁴ Fujin Hou,⁵ Honggang Gao,³ Yufeng Bi,⁶ Haixing Zhang,⁷ and Meng Guo ⁴

¹National Center for Materials Service Safety, University of Science and Technology Beijing, Beijing 100083, China

²Scientific Observation and Research Base of Transport Industry of Long Term Performance of Highway Infrastructure in Northwest Cold and Arid Regions, Gansu 736200, China

³Gansu Henglu Traffic Survey and Design Institute Co.,Ltd, Gansu 730030, China

⁴The Key Laboratory of Urban Security and Disaster Engineering of Ministry of Education, Beijing University of Technology, Beijing 100124, China

⁵Shandong Hi-Speed Construction Management Group Co.,LTD, Jinan 250001, China

⁶Shandong Provincial Communications Planning and Design Institute Group Co.,LTD, Jinan 250101, China

⁷China Communications Construction Company First Highway Bureau Southwest Engineering Co.,Ltd, Sichuan 610000, China

Correspondence should be addressed to Meng Guo; gm@bjut.edu.cn

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With extremely bad climate and poor geographical environment in cold and arid region, the deterioration and failure of road materials are serious. In order to analyze the characteristics of natural aging behavior of asphalt binder in cold and arid region, the experiments were carried out based on the exposure field test base. The multiscale characterization of virgin asphalt under different natural aging conditions was carried out by means of macromechanical analysis and microchemical composition analysis. The results showed that the effects of natural aging and laboratory simulated aging on asphalt binder properties were similar. There was little effect on the performance of asphalt binder after natural aging one year. The effect of natural aging on asphalt binder in one year was similar to that of laboratory short-term aging. However, the strong UV radiation was a great challenge for asphalt pavement in Northwest China. Wind, dust, rain, and other factors have little effect on asphalt binder aging. Affected by the natural environment, macromolecular structures such as oxygen-containing polar functional groups will form in asphalt binder. The molecular weight of asphalt binder was increased, and the internal molecules of asphalt binder were subjected to large internal friction resistance in the process of movement. The macroscopic physical properties and road performance of asphalt binder become poor.

1. Introduction

Northwest China accounts for 42% of China's national area and is a typical cold and arid region in natural regionalization [1]. With extremely bad climate and poor geographical environment, the service life of the asphalt pavement is far lower than the design life [2]. Most areas of Northwest China belong to arid and semiarid climate, with an average rainfall of 45.3 mm and evaporation of 3410.6 mm. The total sunshine hours in the whole year are

3360 hours, the average maximum temperature is 24.9°C, and the average minimum temperature is -10.4°C. The annual average temperature difference exceeds 30°C, and the freezing and thawing days exceed 100 days. It is also affected by complex deterioration factors, such as strong wind, saline soil, and strong ultraviolet (UV) radiation. Asphalt pavement is exposed to the complex environment for a long time. The aging and failure of road materials are serious. The aging of asphalt binder affects asphalt pavement in many ways and makes it embrittle, of reduced damage tolerance and less

durable [3]. It caused the asphalt mixture to become excessively hard and brittle and susceptible to disintegration and fatigue cracking at low temperatures [4, 5]. As a result, the environmental factors easily accelerate the road diseases, such as cracking, loosening, and disintegration [6]. It will greatly reduce the service life of asphalt pavement. The service life of asphalt pavement is greatly reduced, which brings great challenges to pavement maintenance. The deterioration of the properties of the pavement materials during the service life of asphalt pavement is one of the main reasons for the pavement diseases [7]. Asphalt binder is a kind of high-efficiency binder, which plays an important role in bonding the constituent materials of asphalt mixture. The properties of asphalt binder play a decisive role in the quality and durability of asphalt mixture [8, 9].

The accelerated simulated aging test in the laboratory generally requires some forced aging of asphalt binder to enlarge the natural environmental factors. Generally speaking, the aging conditions are more severe than the external effects, so as to obtain a large amount of data in a short time. Based on laboratory accelerated simulated aging test, the studies have made it clear that asphalt binder will gradually undergo oxidation and aging under the effect of the external environment. Then, it becomes hard and brittle, and the bonding ability decreases, which will significantly reduce the performance of asphalt pavement [9–11]. A large number of studies have clarified the effect of aging on the macroproperties of asphalt binder samples. However, asphalt has about 105–106 different molecular types, and its chemical composition is very complex [12–14]. The changes of chemical composition of aged asphalt binder samples were also explored, but the internal aging process of asphalt binder was not clear. For example, Ruan et al. [15] found that aging further hardened the asphalt binder. It increased the viscosity but reduced ductility. Xu et al. [16] found that after aging, the rheological properties of asphalt binder decreased significantly. The complex modulus increased, but the phase angle decreased. Liu et al. [17] found that after aging, the low-temperature crack resistance decreased, but the high-temperature rutting resistance improved. The rutting factor of asphalt binder increased by 4.5 times, and the creep rate at -18°C was 3 times that of unaged asphalt binder.

The research has also explored the effect of aging on the chemical composition of asphalt binder. Under the conditions of high temperature, oxygen, and UV radiation, the light components of asphalt binder will evaporate, and the light components will change to heavy components. The polar functional groups will increase, and the average molecular weight will increase [18]. For example, Guo et al. [19] used Corbett separation method to separate the asphalt binder under different aging conditions. With the deepening of aging degree, the proportion of aromatics gradually decreased, the proportion of asphaltenes gradually increased, and there was no obvious change in saturates and resins content. It was because in the short-term aging process, more aromatics were transformed into resins, and relatively less resins were transformed into asphaltenes. Menapace et al. [6] believed that chemical reactions such as addition will occur after asphalt binder aging to generate long-chain

compounds, and aromatics and colloids will be transformed into asphaltenes. Xing et al. [20] studied the changes of functional groups of asphalt binder before and after aging by atomic force microscope infrared spectroscopy. The results showed that the contents of carbonyl and sulfoxide groups increased. Relying on the accelerated aging simulation test of asphalt binder, researchers have carried out more research on the macro- and microproperties changes in the aging process asphalt binder. It will be used as a reference for studying the natural aging behavior of asphalt binder.

Due to the comprehensive effects of complex natural environment, such as weathering, cold, UV radiation, and chemical corrosion, asphalt binder has extremely complex aging behavior. Compared with other mild climate region, the aging behavior characteristics of asphalt binder under natural conditions in cold and dry areas are more obvious. Compared with the accelerated simulated aging test, the environmental factors of simulated aging test are relatively single. For example, the short-term aging simulates the aging of asphalt binder during pavement construction through the action of 163°C high temperature and oxygen. The long-term aging simulates the aging of asphalt binder during pavement service with 2.1 MPa pressure and 100°C high temperature. The photooxidative aging simulates the exposure of asphalt binder to UV radiation through the UV irradiation of high-pressure mercury lamp aging due to the action of oxygen [21]. The interaction and coupling effects of various factors are not considered, and the effects of such as rainfall, acid-base, and various chemical media are ignored. The simulation results are different from the actual service environment of asphalt pavement. The special environmental characteristics of cold and arid region play a role in accelerating aging and weakening the disadvantage of too long exposure test cycle of natural environment. The research results can clarify the impact of different natural environmental parameters on the service properties of asphalt binder in cold and dry region and then carry out targeted transformation and upgrading of asphalt binder to adapt to the road environment in cold and arid region. In addition, the natural aging data cannot be achieved under laboratory conditions, and the research results can effectively solve the problem of inconsistency between the test data and the actual data. It can be used to optimize the accelerated aging device in the laboratory and greatly improve the evaluation parameters related to the aging properties of road materials in Northwest China.

The objectives of this research are to explore the effects of different natural environmental parameters on the service properties of asphalt binder in cold and arid region and to analyze the characteristics of natural aging behavior of asphalt binder. In this study, combined with the complex climate environment in Northwest China, the experiments were carried out based on the exposure field test base. The multiscale characterization of virgin asphalt binder under different aging conditions was carried out by means of macromechanical analysis and microchemical composition analysis. The effect of natural aging on the macroproperties of virgin asphalt binder was qualitatively analyzed based on rheological properties. The effect of natural aging on the

chemical composition of virgin asphalt binder was analyzed based on chemical functional group and average molecular weight. The effects of different natural environmental factors on asphalt binder aging performance in cold and arid region were studied and analyzed. The evolution law of asphalt binder natural aging in cold and arid region was revealed. It is of great significance to the evaluation of aging performance and the improvement of antiaging performance of road materials in cold and arid region.

2. Materials and Test Methods

2.1. Experimental Materials. Virgin asphalt binder was used for relevant research, and a 90# virgin asphalt binder form Karamay was selected as the test sample.

2.2. Laboratory Ageing. As shown in Figure 1, the asphalt binder was put into the rolling thin film oven (RTFOT). The aging temperature was set to 163°C, and the aging time was 75 min. The short-term aged asphalt binder was obtained. Then, the short-term aged asphalt binder was put into pressure aging vessel (PAV). The aging temperature was set to 100°C, and the pressure was set to 2.1 MPa. After aging for 20 h, long-term aging asphalt binder was obtained.

2.3. Natural Aging Test of Asphalt Binder in Exposed Field. As shown in Figure 2, the natural aging test of asphalt binder was carried out based on the natural exposure site in the northwest cold and arid region with typical climate, such as strong UV radiation, large temperature difference, extreme drought, cold strong wind, and so on. According to the data of a meteorological station in Dunhuang city in 2020, the maximum temperature in summer is 48°C. The maximum temperature of asphalt pavement will reach 80°C. The monthly average daily ultraviolet radiation is 184.33 (J/cm²·d). The average annual rainfall is less than 50 mm. The unaged asphalt binder sample was naturally aged in the exposure field. The film thickness of the asphalt binder sample was 3.18 mm, and the aging cycle of the test sample was 1 year. The asphalt binder sample shown in Figure (a) was directly exposed to the natural environment. The asphalt binder was aged under the comprehensive effect of the natural environment, which was recorded as all-weather (All) aging. The asphalt binder sample shown in Figure (b) was covered by an opaque plate. The asphalt binder was naturally aged to isolate UV radiation, water, wind, dust, and other factors, which was recorded as thermal oxygen (TO) aging. The asphalt binder sample shown in Figure (c) was covered with transparent plate. The asphalt binder was aged to isolate water, wind, dust, and other factors, which was recorded as thermal oxygen + UV (TO+UV) aging. The asphalt binder samples after natural aging were shown in Figure 3.

2.4. Test Methods

2.4.1. Macroproperties Characterization of Asphalt Binder. In this study, DSR-2 produced by TA company from American was used to evaluate the macroproperties of

asphalt binder samples. The parallel plates with diameter of 25 mm and thickness of 1 mm were selected. The temperature was 35°C, 45°C, and 55°C. 0.015% strain control mode was selected in the test, and the scanning frequency was from 0.1 rad/s to 100 rad/s. Based on 45°C, the complex modulus frequency curve and phase angle frequency curve at each temperature were translated according to the time-temperature superposition principle. The complex modulus master curve was obtained to characterize the viscoelastic properties of different kinds of asphalt binders.

Parallel plates with diameter of 25 mm and thickness of 1 mm were selected. The frequency was set at 10 rad/s, and the strain was set at 1%. The test took 46°C as the starting temperature, and the temperature raised automatically every 6°C, and finally raised to 82°C. The curves of rutting factor ($G^* / \sin \delta$) with temperature were obtained. The curve varying with temperature was used to characterize the high-temperature rutting resistance of different kinds of asphalt binders.

Parallel plates with diameter of 4 mm and thickness of 1 mm were selected. The angular frequency range was 0.1–100 rad/s, and the temperatures were –18°C, –12°C, and –6°C. The loss modulus and storage modulus of asphalt binder samples were measured, and then, the stiffness modulus S and creep rate m of asphalt binder samples at –6°C, –12°C, and –18°C were calculated to characterize the low-temperature cracking resistance of asphalt binder.

2.4.2. Microproperties Characterization of Asphalt Binder. Spectrum II infrared spectrometer produced by American PE company was selected for the test. The resolution is 0.5 cm⁻¹, the scanning times are 32, and the wave number is 4000–500 cm⁻¹. The asphalt binder sample was heated to flow in a 135°C oven and then evenly applied to the test bench for testing. The atlas of asphalt binder samples was obtained and analyzed by OMNIC software.

The Waters 515-717-2410 GPC System gel chromatograph was selected, and the refractive index detector-Waters 2410 was used for the test. The polystyrene standard sample (PS) was used as the calibration method to calculate the molecular weight. The peak molecular weight range of polystyrene standard sample is 1.62–2300000. A total of 14 PS standard sample points were used to fit the molecular weight calibration curve. In the test, the asphalt binder sample was prepared with the concentration of 10–15 mg/ml, and THF was used as the mobile phase. The leaching rate was 1 ml/min, and the average molecular weight was obtained.

3. Results and Discussion

3.1. Effect of Natural Aging on the Rheological Properties of Asphalt Binder. Asphalt binder is a kind of viscoelastic material, which is solid at room temperature and low temperature and viscous liquid at high temperature. The service properties of asphalt binder are not only affected by temperature but also related to loading rate, load size, and loading time. The conventional test methods of asphalt



FIGURE 1: Aging instrument for asphalt binder. (a) RTFOT. (b) PAV.

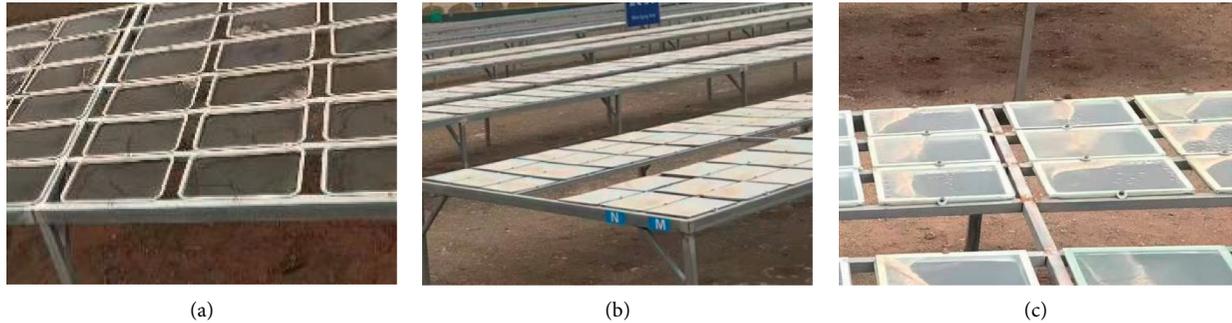


FIGURE 2: The natural aging test of asphalt binder. (a) All; (b) TO; (c) TO + UV.

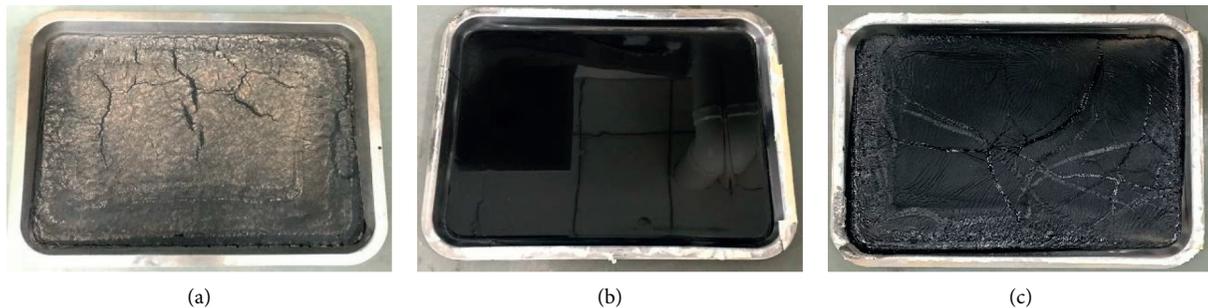


FIGURE 3: The asphalt binder sample after natural aging. (a) All; (b) TO; (c) TO + UV.

binder have defects in studying the viscoelastic properties of asphalt binder. At present, the rheological method is widely used to characterize the viscoelastic properties of asphalt binder [22]. SHRP plans in United States use dynamic shear rheometer to evaluate the rheological properties of asphalt binder in the road properties specification of asphalt binder. It can also objectively reflect the high-temperature performance, low-temperature performance, and fatigue performance of asphalt binder.

3.1.1. The Effect of Natural Aging Based on Viscoelastic Properties. In order to study the effect of natural aging on viscoelastic properties of asphalt binder, dynamic shear rheological tests were carried out on virgin asphalt binder samples. According to the time-temperature equivalence principle, the complex modulus curve at each temperature can be translated along the horizontal direction to obtain the complex modulus master curve based on the reference

temperature (45°C in this test). It can represent the rheological characteristics of asphalt binder at a wider frequency (wider temperature range), as shown in Figure 4.

It can be seen from Figure 4 that the complex modulus master curve of virgin asphalt binder increases obviously after aging in different ways. It showed that the modulus of asphalt binder increased after aging. The viscous component in asphalt binder decreased, but the elastic component increased. The asphalt binder hardened and became brittle, resulting in the enhancement of deformation resistance and the weakening of viscoelastic properties. It can be seen from Figure 4 that the natural aging of the three modes improved the complex modulus of asphalt binder. However, the increased degree was similar to that of short-term aging. It indicated that natural aging had little effect on the viscoelastic properties of asphalt binder.

In comparison, all-weather aging and thermal oxygen + UV aging had a greater impact on asphalt binder than thermal oxygen aging. The effect of thermal oxygen aging on

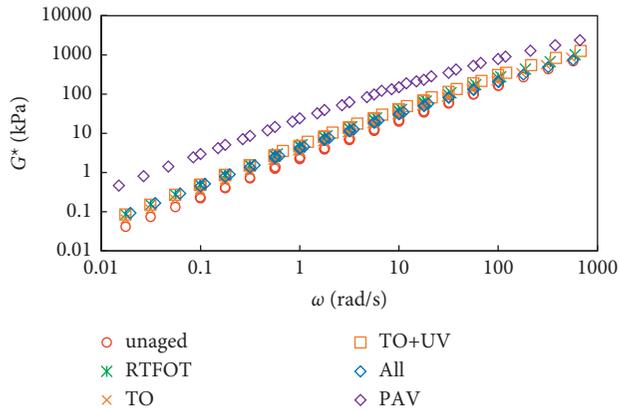


FIGURE 4: Master curve of complex modulus of asphalt binder before and after aging.

asphalt binder was less than that of short-term aging in laboratory. At low frequency (high temperature), the complex modulus of asphalt binder aged by the all-weather aging and thermal oxygen + UV aging increased relatively greatly. At high frequency (low temperature), the increase in thermal oxygen + UV aging was the most obvious, which was almost close to the long-term aging asphalt binder in the laboratory. It can be seen that UV radiation had a great impact on asphalt binder in cold and arid region. The experimental data also showed that the effects of laboratory short-term aging on viscoelastic properties of asphalt binder were matched to natural aging for one year in cold and arid region.

3.1.2. The Effect of Natural Aging Based on High-Temperature Properties. In order to study the effect of natural aging on the high-temperature properties of asphalt binder, the dynamic shear rheological test of virgin asphalt binder samples was carried out to obtain the rutting factor ($G^* / \sin \delta$). Rutting factor reflects the dynamic rheological properties and permanent deformation resistance of asphalt binder. It is used as the evaluation index of high-temperature rutting resistance of asphalt binder in American Superpave Asphalt Performance specification. The rutting factor was larger, and the asphalt binder flow deformation capacity was smaller at the same temperature. At high temperature, the rutting resistance was stronger. The variation curve of rutting factor with temperature was shown in Figure 5.

It can be seen from Figure 5 that with the increase in temperature, the asphalt binder became soft, and the rutting resistance decreases gradually. After aging in different ways, the rutting factor of virgin asphalt binder increased obviously at the same temperature. It can be seen that the aging effect made the asphalt binder harden, the flow deformation became smaller, and the rutting resistance at high temperature was also improved. Compared with the long-term aging in the laboratory, it can be found that the increased rutting factor of asphalt binder samples aged for one year was small, and its effect of the high-temperature properties of asphalt binder was also small. It indicated that natural

aging had little effect on the high-temperature properties of asphalt binder.

The rutting factor of thermal oxygen aged asphalt binder was less than that of laboratory short-term aged samples at the same temperature. It showed that the effect of thermal oxygen aging on asphalt binder was small. In comparison, all-weather aging had the greater impact on asphalt binder. It can be seen that the addition of UV radiation, wind, and dust had a great effect on the high-temperature properties of asphalt binder. Among them, the effect of all-weather aging on asphalt binder aging high-temperature performance was similar to that of thermal oxygen + UV aging. However, they were much greater than that of thermal oxygen aging. It can be seen that UV radiation contributes greatly to asphalt binder aging in cold and arid region. The experimental data also showed that the effects of laboratory short-term aging on high-temperature performance of asphalt binder were lower to natural aging for one year in cold and arid region.

3.1.3. The Effect of Natural Aging Based on Low-Temperature Properties. Asphalt binder will harden obviously at low temperature, which was characterized by Hooke elastomer. At low temperature, the asphalt binder will deform at the moment of stress application. The stiffness modulus S is used in Superpave to reflect the flexibility of asphalt binder. At low temperature, the greater the stiffness modulus of asphalt binder, that is, the smaller the creep compliance, the worse its deformation adaptability, and the smaller the allowable deformation. Under the action of external force or when the temperature continues to decrease, the greater the stress change of asphalt binder due to shrinkage strain, the worse the low-temperature crack resistance. The creep rate m was used to reflect the relaxation capacity of asphalt binder under stress. The greater the value of m , the greater the deformation capacity, and the stronger the relaxation capacity. Asphalt binder often had good low-temperature crack resistance. The test results are shown in Figure 6.

Comparing the data in Figures 6(a) and 6(b), it can be seen that under the three test temperatures, the stiffness modulus S of virgin asphalt binder after aging increased, the creep rate m value decreased. The results show that aging reduced the flexibility of virgin asphalt binder at low temperature and improved the possibility of low-temperature cracking. On the whole, natural aging had a great impact on the low-temperature performance of asphalt binder. The effect of natural aging on asphalt binder in different ways was greater than that of short-term aging. Thermal oxygen + UV aging and all-weather aging have the greatest impact on the aging of asphalt binder. It was close to the S value and m value of long-term aging.

At -6°C , the effect of different aging methods on asphalt binder at low temperature was as follows: long-term aging > all-weather aging > thermal oxygen + UV aging > thermal oxygen aging > short-term aging. It can be seen that with the increase in environmental factors, the natural aging degree of asphalt binder gradually increased, but it was still less than the effect degree of long-term aging. At -12°C , the effect of aging methods on the low-temperature

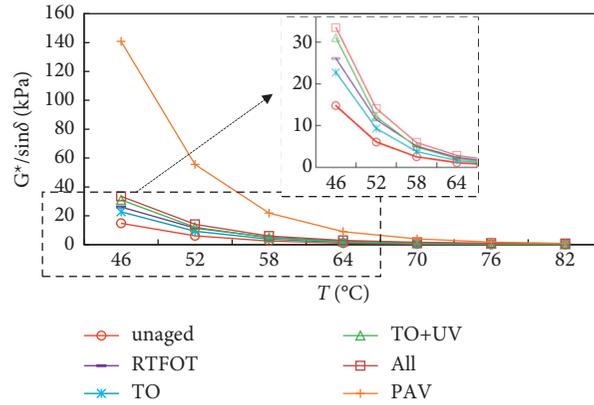


FIGURE 5: The variation curve of rutting factor with temperature of asphalt binder before and after aging.

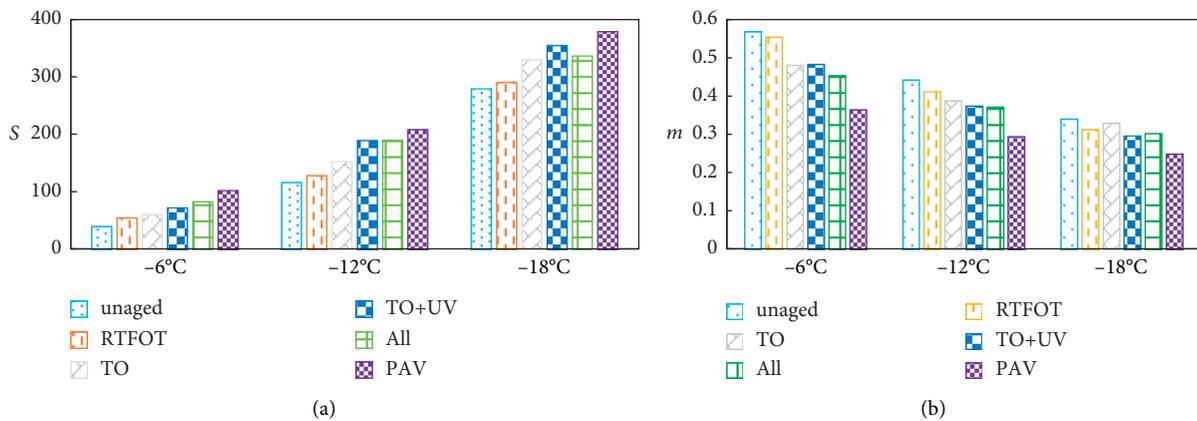


FIGURE 6: The stiffness modulus and creep rate of asphalt binder before and after aging. (a) Stiffness modulus S . (b) Creep rate m .

properties of asphalt binder was similar to that at -6°C . However, at this temperature, the effect of thermal oxygen + UV aging on asphalt binder was the same as that of all-weather aging. At -18°C , the effect degree of thermal oxygen + UV aging was greater than that of all-weather aging. It can be seen that with the decrease in temperature, the effect of wind, dust, rain, and other factors will gradually reduce the aging degree of asphalt binder. It was related to covering the all-weather aging surface, reducing the contact area between the asphalt binder and the external environment, and reducing the aging of asphalt binder by oxygen and UV radiation. It also showed the great effect of UV radiation on the properties of asphalt binder in cold and arid region.

In conclusion, the impact of natural aging on the properties of asphalt binder is similar to that of laboratory simulated aging, which will reduce the viscoelastic properties of asphalt binder and increase the risk of low-temperature cracking. The deformation resistance of asphalt binder was enhanced, and the rutting resistance at high temperature was improved. However, one year of natural aging had little effect on the aging degree of asphalt binder. Among them, the thermal oxygen aging degree of asphalt binder was the smallest, which was similar to that of short-term aging degree. It indicated that the factors such as large temperature difference and high temperature in Northwest

China have a certain effect on asphalt binder aging, but the effect range was small. The natural aging degree of thermal oxygen + UV aging asphalt binder was large, and the deepening of UV aging degree of asphalt binder can be obviously felt. Strong UV radiation is a great challenge for asphalt pavement in Northwest China. Rain, wind, and dust have little effect on asphalt binder aging. They even cover the all-weather aging surface, reducing the contact area between the asphalt binder and the external environment. The aging of asphalt binder by oxygen and UV radiation was reduced.

3.2. Effect of Natural Aging on the Chemical Composition of Asphalt Binder

3.2.1. The Effect of Natural Aging Based on Functional Group.

FTIR is a rapid method to analyze the information of functional groups in organic materials. It can judge whether there is a certain type of functional group in the molecule according to the wave number, peak shape, intensity, and quantity of the spectrum in the scanned sample spectrum. Then, the different types of functional groups in asphalt binder are evaluated. FTIR was used to analyze the functional group information of virgin asphalt binder undergoing different aging modes. The results were shown in Figure 7.

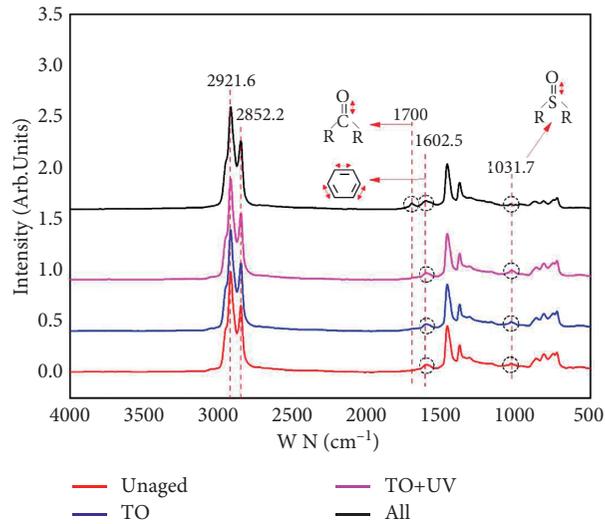


FIGURE 7: FTIR spectrum of asphalt binder before and after natural aging.

As shown in Figure 7, the unaged virgin asphalt binder contained a variety of characteristic peaks, including the antisymmetric stretching vibration peak of methylene ($-\text{CH}_2-$) of 2920 cm^{-1} , the symmetrical stretching vibration peak of methylene ($-\text{CH}_2-$) of 2850 cm^{-1} , the C-H plane stretching vibration peak in methyl (C-CH₃) of 1460 cm^{-1} , the C-H plane stretching vibration peak in $-\text{CH}_2-$, and the $-\text{CH}_3$ symmetrical variable angle absorption peak of 1376 cm^{-1} . All these showed that asphalt binder is mainly composed of alkanes. The absorption peak near 1600 cm^{-1} is partly caused by the skeleton vibration of benzene ring. Therefore, it can be judged that there are aromatic compounds in asphalt binder. The carbonyl absorption peak is between 1800 and 1650 cm^{-1} . The absorption peak of sulfoxide group is near 1030 cm^{-1} . Carbonyl group and sulfoxide group were often used to characterize the aging of asphalt binder [23].

It can be found that the characteristic absorption peaks of asphalt binder before and after aging were roughly unchanged by comparing the unaged asphalt binder and natural aged asphalt binder. There were strong absorption peaks in the wave number range of 2852 – 2958 cm^{-1} , and there was no change in the height of the peak before and after aging. It showed that aging has little effect on alkanes, such as C-H, C-CH₃ and C-CH₂- in asphalt binder. According to Lambert-Beer law, the absorption peak intensity of functional groups was directly proportional to their concentration. The carbonyl characteristic peak of all-weather aged asphalt binder appeared at 1700 cm^{-1} . There was no obvious absorption peak in other natural aging asphalt binder samples. It can be found from 1600 cm^{-1} that the absorption peak of all-weather aged asphalt binder and thermal oxygen + UV aged asphalt binder was slightly higher than that of unaged asphalt binder. It showed that aging will increase the content of aromatic rings in asphalt binder. On the whole, although natural aging had little effect on the functional group composition of virgin asphalt binder, it still increased the content of polar functional groups. The content of carbonyl and sulfoxide increased obviously after the addition of UV radiation. It showed that the virgin asphalt binder will absorb oxygen

during natural aging and generate oxygen-containing polar functional groups, such as carbonyl and sulfoxide.

3.2.2. *The Effect of Natural Aging Based on Average Molecular Weight.* According to different statistical average methods, the average molecular weight can be calculated as follows.

$$\begin{aligned}
 M_n &= \frac{\sum N_i M_i}{\sum N_i} = \frac{\sum W_i}{\sum W_i / M_i} \\
 M_w &= \frac{\sum N_i M_i^2}{\sum N_i M_i} = \frac{\sum W_i M_i}{\sum W_i} \\
 M_z &= \frac{\sum N_i M_i^3}{\sum N_i M_i^2} = \frac{\sum W_i M_i^2}{\sum W_i} \\
 D &= \frac{M_w}{M_n}
 \end{aligned} \tag{1}$$

where M_n = average molecular weight calculated by molecular number; M_w = average molecular weight calculated by molecular weight; M_z = average molecular weight calculated by Z-value; M_i = average molecular weight; N_i = molecular number; W_i = molecular weight; D = polydispersity index.

The average molecular weight of virgin asphalt binder samples with different aging methods were shown in Table 1.

It can be seen from Table 1 that the values of the average molecular weight calculated by different statistical methods of asphalt binder samples were increased after natural aging. From the perspective of M_n , thermal oxygen + UV aging had the greatest impact on asphalt binder samples. However, from the perspective of M_n , M_z , and D , the effect of different aging conditions on asphalt binder aging was as follows: All weather aging > thermal oxygen + UV aging > thermal oxygen aging. It showed that the molecular weight of asphalt binder increased after natural aging, which also complicated the internal ring structure of asphalt binder. In comparison,

TABLE 1: The average molecular weight of asphalt binder samples.

Samples	M_n	M_w	M_z	D
Unaged	385	1163	2945	3.0208
TO	506	1255	2813	2.4802
TO + UV	524	1488	3923	2.8397
All	474	1684	4060	3.4770

TABLE 2: The effect degree of different natural aging methods on the properties of asphalt binder.

Properties	Effect
Viscoelastic properties	TO + UV > all > TO
High-temperature performance	All > TO + UV > TO
Stiffness modulus at -6°C	All > TO + UV > TO
Stiffness modulus at -12°C	All = TO + UV > TO
Stiffness modulus at -18°C	All > TO + UV > TO
Functional group	All > TO + UV > TO
M_n	TO + UV > TO > all
M_w	All > TO + UV > TO

thermal oxygen aging had little effect on asphalt binder. The effect of thermal oxygen + UV aging on asphalt binder is relatively large, which is similar to that of all-weather aging. It can be seen that the addition of UV radiation had a great impact on asphalt binder.

3.2.3. The Effect of Natural Aging on Asphalt Binder. The effect degree of different natural aging methods on the macro- and microproperties of asphalt binder was shown in Table 2.

As shown in Table 2, different natural aging methods had similar effects on the macro- and microproperties of asphalt binder at the same aging time. It showed that the aging degree increases with the increase of aging factors, but the action of wind, dust, and rain had antiaging effect on asphalt binder. They can cover the all-weather aging surface, reducing the contact area between the asphalt binder and the external environment.

Functional groups were formed by oxygen absorption during natural aging of asphalt binder. There were permanent dipoles between polar functional groups and electrostatic forces between them during movement. It can accelerate the addition and association of small molecules and produce more macromolecules or larger molecules. The intermolecular force was enhanced, and the molecular weight of the material was increased. The molecular weight of materials was closely related to their properties [24]. The movement of molecules in substances with large molecular weight was subject to large internal friction resistance. The free movement between molecules will be limited, it was not easy to move, and the overall modulus of the material will be high. At high temperature, the internal molecular movement of aging asphalt binder requires more energy, and the high-temperature performance will be increased. At low temperature, the internal molecules of asphalt binder were not easy to move, the asphalt binder was hard and brittle, and the low-temperature performance was poor.

4. Conclusion

Combined with the complex climate environment in the cold and arid region of Northwest China, the effect of natural aging on the macro- and microproperties of virgin asphalt binder was analyzed. It was comprehensively analyzed by means of macromechanical analysis and microchemical composition characterization. The evolution law of asphalt binder natural aging in cold and arid region was revealed. The main conclusions of this study were as follows:

- (1) The effects of natural aging and laboratory simulated aging on asphalt binder properties are similar. The aging degree of natural aging on asphalt binder in one year is similar to that of laboratory short-term aging. It will reduce the viscoelastic properties of asphalt binder, increase the risk of low-temperature cracking, and enhance the deformation resistance of asphalt binder.
- (2) There was little effect on the aging performance of asphalt binder after natural aging one year. The aging degree of asphalt binder was obviously deepened by UV radiation in Northwest China. Strong UV radiation was a great challenge for asphalt pavement in Northwest China. Wind, dust, rain, and other factors have little effect on asphalt binder aging.
- (3) Affected by the natural environment, macromolecular structures such as oxygen-containing polar functional groups will form in asphalt binder. The molecular weight of asphalt binder was increased, and the internal molecules of asphalt binder were subjected to large internal friction resistance in the process of movement. The macroscopic physical properties and road performance of asphalt binder become poor.
- (4) Finally, it is worth noting that the natural environment will give a great effect on asphalt pavement, and further studies should be conducted to evaluate the effect of natural environment on the aging performance of asphalt mixture and pavement structure.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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