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Experimental study of water aging on asphalt during service life of pavements

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Abstract: In order to further simulate the real condition of pavements during the service life, moisture is considered in long-term aging tests based on the existing researches about thermal aging and oxidation aging of asphalt. Water is injected into the pressure aging vessel (PAV) to simulate the aging process during the service life. The performance-based strategic highway research program (SHRP) parameters $G^*/\sin\delta$ and $S(t)$ are adopted to evaluate the high-temperature properties and low-temperature properties of the aged asphalt, respectively. The Thailand 90# asphalt, the modified Thailand 90# asphalt and the Shell 70# asphalt are used in the test. It is found that the moisture has a significant influence on parameter $G^*/\sin\delta$ when combined with heat and oxygen, so water aging makes high-temperature performance decay more seriously. But the low-temperature performance does not change remarkably after water aging. Since the influences of temperature, oxygen and water are taken into account in the PAV test, the accuracy of asphalt aging tests can be improved and the long-term aging process of asphalt pavement can be exactly simulated.

Key words: asphalt; water aging; SHRP method; service life

The properties of asphalt become worse gradually during the mixing operation and the service life of pavements. The aging speed of asphalt is related to the conditions of the asphalt pavement, which is one of the main factors of asphalt pavement durability[1-2]. During the service life of asphalt, oxygen is the main inherent factor of asphalt aging while heat is the main external factor, and the service time directly affects the aging degree of asphalt. In addition, rainwater and ultraviolet rays are the important influencing factors on asphalt aging that should not be ignored[3-4].

Much research[1-5] shows different roles of oxidation aging, thermal aging, ray aging of asphalt and the interaction with each other. They indicate that though asphalt is a hydrophobic material, the soluble composition in it can be scoured off by rainwater, and this will cause the asphalt to deteriorate. They also show that the pH value of water has a significant influence on the interface oil-water tension of asphaltenes and acids in asphalt. Wu et al. [2,6] enumerated some reasons for asphalt aging and pointed out that water impelled the asphalt aging in the whole layer of asphalt pavements with the help of the factors such as heat, oxygen and sunshine. With a long time of sunlight exposure, the ultraviolet ray in sunlight exerted a tremendous influence on asphalt aging of the pavement surface. The tests indicate that the relative carbonyl index signifies the aging degree of asphalt and the index is obviously influenced by the sunlight. According to Ref. [1], when the wavelength of ultraviolet rays is 550 μm, the depth that it penetrates the asphalt is only 0. 1 mm. With the molecules of aged asphalt pervading inside, the ultraviolet rays only affect the top pavement layer of aging asphalt by no more than 1 mm. So the sunlight is not considered as an aging factor in the rolling thin-film oven test (RTFOT) which is also regarded as a short-term aging test. The pressure aging vessel (PAV) test is regarded as a long-term aging test; however, the whole asphalt pavement layers become worse under the action of rainwater and groundwater during the service life, so it is worthwhile to study the influence of water on long-term aging tests of asphalt.

During oxidation aging, there are chemical changes in oxygen and the active base groups of asphalt are oxidized, so an oxygen-carbonyl functional group is produced. During the thermal aging of asphalt, the light oil component of asphalt volatilizes constantly due to heat, so the structure of the asphalt component is changed. High temperatures also make the unsaturated pair of keys in asphalt molecules disappear and make the structure of asphalt change greatly. Consequently, asphalt performance decays seriously [7-8].

The asphaltene can reduce the interface tension of asphalt and water. The asphaltene contains many polarity base groups, such as —OH, —NH_2, —COOH, etc., which can make asphaltene molecules move to the asphalt/water interface to form stronger structure membranes[9]. Further study shows that the complicated molecular structure and aggregation propensity of asphaltene obviously make the interface structure membrane scleroses during the service life. Because of the heat and oxygen, the sclerosis speed is aggravated, which makes the sclerosis transformation irreversible. Thus the asphalt performance becomes worse.

In this paper, moisture is considered as an influencing factor in the PAV test. The properties of the aged asphalt are studied by using the SHRP parameters when the influences of moisture are taken into account. The SHRP parameters such as $G^*/\sin\delta$ and $S(t)$ relate to the pavement serviceability, so $G^*/\sin\delta$ and $S(t)$ are adopted to evaluate the high-temperature properties and low-temperature properties of the aged asphalt, respectively[10-11]. The asphalt aging mechanism is more clear and the simulation method of asphalt aging indoors is improved by the study in this paper.

1 Instrument and Test Method

There are two kinds of asphalt aging. One is long-term aging and it occurs during the service life of the pavement; the other occurs during construction which is termed as

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short-term aging.

Early in the 19th century, the Highway Scientific Research Institute of the Ministry of Communications manufactured an aging case that can simulate the natural environment of aging, such as sunshine, drench, ultraviolet rays, etc. In Japan, different climatic conditions of the field are thoroughly taken into account to simulate asphalt aging, including carbon arc lamp, ultraviolet ray, drenching, etc. But there is not a standard experimental method. In the 1990s, the PAV test method was proposed in the SHRP. The PAV test is a standard method for long-term aging testing of asphalt that has been accepted by the public. According to different conditions of the environments, the test temperature of the PAV can be modulated to 90, 100 and 110 ℃, and the pressure of oxygen in the container is 2.1 MPa.

The PAV can be used to simulate thermal aging and oxidation aging of asphalt. It has already shown that sunlight only influences the top layer of the pavements, so light is not considered for asphalt aging. However, water is an important environmental factor and its effects on the all levels of asphalt pavements may last for a long period as heat and oxygen do. So water should be considered as an influencing factor in the long-term aging of asphalt.

In this test, water steam is put into the PAV first and the pressure is 0.2 MPa without oxygen, then oxygen is put into the PAV and the pressure increases to 2.1 MPa. Through the test, we obtain the asphalt that has been synthetically aged by thermal energy, oxidation and water. The high-temperature and low-temperature performances of the aged asphalt are tested.

The asphalts tested in this study include the Thailand 90# asphalt (T90#), the modified Thailand 90# asphalt (modified T90#) and the Shell 70# asphalt (S70#). First, the samples are aged in the RTFO for 85 min. Then, the samples are put into the PAV for long-term aging. Each test is accomplished under conditions with water and without water. The asphalt is aged for different times after the PAV test, the high-temperature performance and low-temperature performance of the aged asphalt are tested.

2 High-Temperature Performance

The change of parameter $G^*/\sin\delta$ can signify the high-temperature performance of the aged samples after long-term aging. Fig. 1 and Fig. 2 show the influences of moisture on $G^*/\sin\delta$ of the T90# and the modified T90# in the PAV test for 20 h, respectively.

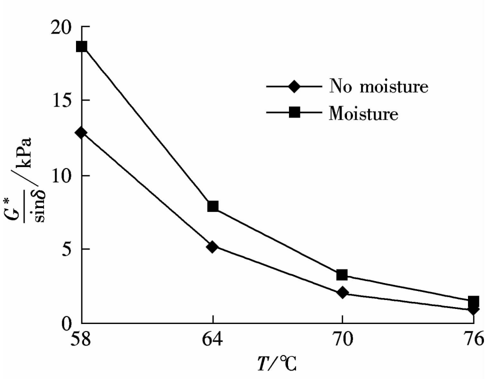

Fig. 1 Influence of moisture on high-temperature performance of T90#

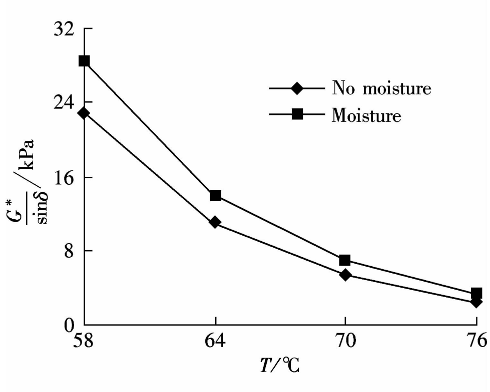

Fig. 2 Influence of moisture on high-temperature performance of modified T90#

The testing results show that no matter whether asphalt or modified asphalt, the existence of moisture has a remarkable influence on the high-temperature performance of aged asphalt.

Fig. 3 shows the influence of aging time on the parameter $G^*/\sin\delta$ at 64 ℃. The results of long-term aging testing indicate that moisture accelerates the aging speed of the asphalt.

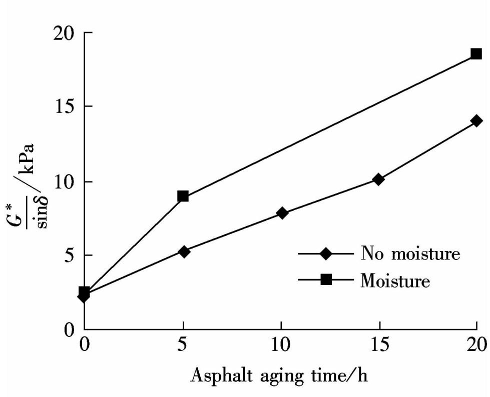

Fig. 3 Influence of different aging levels on $G^*/\sin\delta$ of S70# at 64 ℃

3 Low-Temperature Performance

SHRP parameter $S(t)$, termed as a low-temperature creep modulus of asphalt, can signify the low-temperature performance of asphalt after long-term aging. Fig. 4 and Fig. 5 show the influence of moisture on $S(t)$ of the T90# and the modified T90# in the PAV test for 20 h, respectively.

The testing results show that moisture also impacts the low-temperature performance of asphalt, but the influence is not so remarkable as that on the high-temperature performance of asphalt.

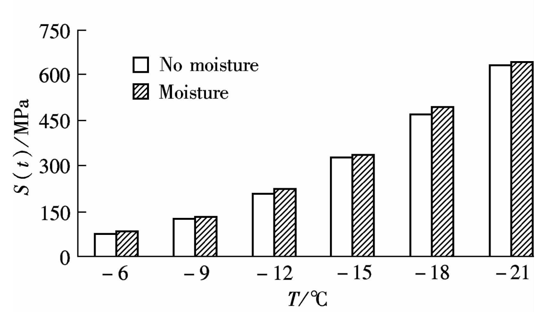

Fig. 4 Influence of moisture on low-temperature performance of T90#

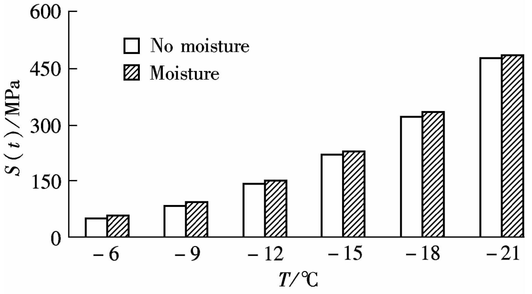

Fig. 5 Influence of moisture on low-temperature performance of modified T90#

Fig. 6 shows the influence of aging time on parameter $S(t)$ at -12℃. The long-term aging test indicates that moisture accelerates the aging speed of asphalt.

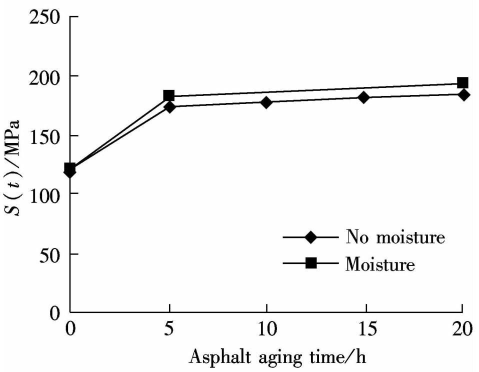

Fig. 6 Influence of different aging levels on $S(t)$ of S70# at -12 ℃

The PAV test for 20 h is designed to simulate aging that occurs at the end of the service life of pavements [12-13]. The residue of the test is used to estimate the physical and chemical properties of asphalt used 5 to 10 years in the field. The properties of recycled asphalt change greatly in the first 30 months of the service life, and the change slows down later. Fig. 3 and Fig. 6 show that the long-term aging test with moisture can simulate the aging process of asphalt in the pavement more accurately.

In addition, Fig. 3 and Fig. 6 show that the influence of moisture on the performance parameter of aging asphalt is the same as the influence of heat and oxygen, but the influence pattern is different. Water aging makes high-temperature performance deteriorate more seriously, but the low temperature performance does not change so much with or without water.

4 Conclusions

The aging of asphalt depends on environmental conditions, such as ultraviolet rays and water conditions. The performance tests of asphalt aging with the function of water are carried out. Conclusions are drawn as follows:

1) Of all the factors in the service life of asphalt pavement, it cannot be ignored that water plays an important role in asphalt aging. The tests indicate that water worsens the aging degree of asphalt which is described by the SHRP parameters $G^*/\sin\delta$ and $S(t)$.

2) The PAV test with the factor of water shows that the asphalt aging is serious in the early stages and the aging speed is fast. Water aging makes high-temperature performance deteriorate seriously. The low-temperature performance does not change very much with water or without water.

3) The PAV test with moisture is a good way to simulate the asphalt aging in the field with the functions of heat, oxygen and water. It is suggested that water should be considered in the PAV test.

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道路沥青使用过程中水老化试验研究

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摘要:在研究沥青材料热氧老化规律的基础上,为进一步模拟路面实际状态,在长期老化试验中引入了水的因素. 采用加水的 PAV(压力老化容器)试验模拟沥青在寿命期的老化过程,以 2 个 SHRP 性能指标车辙因子 $G^*/\sin\delta$ 和劲度模量 $S(t)$ 分别表示沥青的高温和低温性能,并用 90#泰国沥青、90#改性沥青和 70#壳牌沥青进行试验. 结果表明:在水、温度和氧的共同作用下,水对高温性能指标 $G^*/\sin\delta$ 产生显著影响,所以水老化使沥青的高温性能急剧衰退,而对低温性能的影响并不显著. 加水的 PAV 试验综合考虑了水、温度和氧气等环境因素的作用,能够提高模拟试验的精确性,更好地模拟沥青路面使用寿命期的长期老化过程.

关键词:沥青;水老化;SHRP 方法;使用寿命

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