Effects of Mixing Ratio of Old and New Asphalt on Aging Characteristics of Asphalt Cement

Huiqiang Chen, Jianbang Sun, Xiaofeng Guo, Weina Wang and Dalu Liu

ABSTRACT

In order to explore aging characteristics of asphalt cement, the stiffness modulus, creep rate, phase angle and loss modulus of new and old asphalt mixture and recycled asphalt before and after RTFOT & PAV aging were tested by BBR and DSR experiments. The results showed that the modulus, creep rate and phase angle of asphalt cement was effected by RTFOT slightly, while they were effected by PAV relative significantly. After RTFOT and PAV aging, stiffness modulus, creep rate, phase angle and loss modulus of all asphalt samples have undergone significant changes, furthermore, with the increase of recycled asphalt content, the technical indexes(stiffness modulus, creep rate, phase angle and loss modulus) tended to those of pure recycled asphalt. Thereafter, the process of RTFOT and PAV aging of new asphalt may be catalyzed and accelerated by the recycled asphalt on a certain extent.1

KEYWORDS

Rheological Properties, Creep, Aging Characteristics, Catalytic Aging

INTRODUCTION

In recent years, the great developments and applications of asphalt pavement have been gained in our country. However, how to recycle the waste asphalt mixture

1Huiqiang Chen, Jianbang Sun, Xiaofeng Guo Weina Wang, Dalu Liu, Chongqing Jiaotong University, China.
is becoming a common concern for people. At present, the recycling of waste asphalt mixture is mainly realized by means of regeneration[1~3]. But according to the effects of the engineering applications, the durability of recycled asphalt pavement is not ideal, which is perhaps associated with recycled asphalt of mixture. It is regrettable that the reasons for this phenomenon are not clear at present, and the relevant researches are seldom reported[4~5], so the popularization and application of regenerative technologies were limited. Although the performance changing and mechanism of asphalt aging have been studied by many scholars[6~9], having made some achievements, the research that the recycling asphalt catalyzes new asphalt aging has not been reported. Many studies showed that evaluating the aging characteristics of asphalt by SHRP rheological indexes and low-temperature bending test more agreed with object reality[10]. Based on those reasons, the stiffness modulus and creep rate of recycled asphalt, matrix asphalt and their mixture were tested by BBR before and after RTFOT and PAV in this paper. In addition, complex modulus and phase angle have been tested through DSR test to evaluate the aging effect of recycled asphalt on matrix asphalt. Thereafter, the process of RTFOT and PAV aging of new asphalt may be catalyzed and accelerated by the recycled on a certain extent.

ORIGINAL MATERIALS AND TEST METHODS

Original Materials

(1) recycled asphalt: extracted from the waste asphalt mixture from chongqing-suining.
(2) matrix asphalt: zhonghai 70º.
The related technical performance indicators are listed in table 1.

<table>
<thead>
<tr>
<th>Asphalt types</th>
<th>25℃Needle penetration/(0.1mm)</th>
<th>15℃ Ductility/cm</th>
<th>Softening point/℃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhonghai 70º</td>
<td>63.3</td>
<td>135.3</td>
<td>48.9</td>
</tr>
<tr>
<td>Recycled asphalt</td>
<td>35.3</td>
<td>17.4</td>
<td>63.1</td>
</tr>
</tbody>
</table>

Test Methods And Equipment

Low temperature creep test of asphalt(BBR), Semiconductor refrigeration low-temperature bending rheometer 3388-A3005, CANNON INSTRUMENT COMPANY;
Test on rheological properties of asphalt, DHR rheometer, TA Instruments–Waters LLC.

RESULTS AND DISCUSSION

BBR Test

STIFFNESS MODULUS

The stiffness modulus of several asphalt samples before and after aging by RTFOT and PAV was shown in Fig1 and Fig2. In the figures, 100% R represents pure recycled asphalt, 100% A represents pure matrix asphalt, 20%R+80%A represents the mass ratio of recycled asphalt to matrix asphalt is 2:8, 40%R+60%A represents the mass ratio of recycled asphalt to matrix asphalt is 4:6, the same below.

Figure 1. The stiffness modulus asphalt samples before and after RTFOT & PAV (-12°C).

Figure 2. The stiffness modulus asphalt samples before and after RTFOT & PAV (-18°C).
Fig1 and Fig2 showed that the stiffness modulus of almost every asphalt sample subjected to both RTFOT and PAV at -12℃ or -18℃ appeared a similar variation tendency. The effect of RTFOT on the stiffness modulus of asphalt samples was not obvious, while that of PAV was relatively significant, which indicated that the aging of asphalt occurred mainly during the application stage of asphalt mixture. The order of stiffness modulus after RTFOT from large to small was: 100%R>40%R+60%A>20%R+80%A>100%A, which indicated that the addition of recycled asphalt would increase stiffness modulus of the matrix asphalt. Thus, the low temperature performance of asphalt was affected. The stiffness modulus of all asphalt samples after PAV aging went up significantly both at -12℃ and -18℃, indicating that the low temperature performance of asphalt samples was affected relatively significant by PAV aging. It was worth noting that the stiffness modulus of asphalt samples after PAV was increased by adding a certain amount of recycled asphalt, and the stiffness modulus of 40%R+60%A was basically close to that of the pure recycled asphalt. The reason needs to be further studied. It may be due to the existence of a certain amount of free radicals in the recycled asphalt, which caused the polymer chain to break in the process of aging. That is to say, these free radicals may play a catalytic role in the whole process of aging.

**CREEP RATE**

The creep rate of asphalt samples before and after aging by RTFOT and PAV was shown in Figure3 and figure4. The results showed that the creep rate almost appeared a similar variation tendency before aging at both -12℃ and -18℃. The content of recycled asphalt was closely related to the creep rate, the higher the content of the recycled asphalt, the smaller the creep rate, and the same rule applied to after RTFOT and PAV aging. The results indicated that the addition of recycled asphalt was not benefit to the low temperature crack resistance of asphalt cement. At the same time, the aging process also caused the decrease of the asphalt creep rate, but the affection of PAV aging was more significant than that of RTFOT aging, and the effects of aging on low temperature resistance of asphalt cement were also disadvantageous. However, compared with the asphalt creep rate after RTFOT and PAV aging, it can be seen that the creep rate of asphalt samples after RTFOT aging only decreased slightly, while after PAV aging, the “m” value of asphalt samples decreased significantly. Furthermore, except matrix asphalt, the “m” value of other three asphalt was very close, indicating that they had similar low temperature crack resistance at this time. Thereafter, the process of RTFOT and PAV aging of new asphalt may be catalyzed and accelerated by the recycled asphalt, and the reason needs to be further studied. It was possible that the active free radicals existed in the recycled bitumen induced asphalt molecules of the matrix asphalt to catalyze the aging effect.
DSR Rheological Experiments

The asphalt pavement subjected to periodic load, so from the theoretical and practical point of view, the dynamic mechanical behavior of asphalt pavement is a kind of viscoelastic behavior which is close to the actual condition of the material. SHRP results showed that the asphalt binder shear modulus $G^*$ and the phase angle $\delta$ can characterize the viscoelastic properties of asphalt binders. The phase angle is due to the influence of the viscous component material, material input stress and strain response lag angle generated. For the majority of viscoelastic materials including asphalt, the phase angle is: $0<\delta<\pi/2$, so the phase angle reflects the
viscous elastic component of asphalt material ratio, the greater the phase angle, the more viscous component.

The test conditions are as follows: stress control mode is adopted, the stress is 1.5×10^4 Pa, the temperature is 0℃, the frequency is 0.1 Hz. The test results of complex modulus and phase angle before and after aging of asphalt are shown in Table 2.

<table>
<thead>
<tr>
<th>Asphalt type</th>
<th>100%A</th>
<th>20% R+80%A</th>
<th>40% R+60%A</th>
<th>100% R</th>
</tr>
</thead>
<tbody>
<tr>
<td>G*/10^6Pa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>original sample</td>
<td>1.98</td>
<td>2.20</td>
<td>3.25</td>
<td>4.56</td>
</tr>
<tr>
<td>after RTFOT</td>
<td>2.66</td>
<td>2.81</td>
<td>5.13</td>
<td>6.07</td>
</tr>
<tr>
<td>After RTFOT+PAV</td>
<td>4.75</td>
<td>6.32</td>
<td>6.84</td>
<td>7.15</td>
</tr>
<tr>
<td>δ(°)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>original sample</td>
<td>54.16</td>
<td>40.26</td>
<td>36.48</td>
<td>28.74</td>
</tr>
<tr>
<td>after RTFOT</td>
<td>41.87</td>
<td>34.91</td>
<td>30.01</td>
<td>17.69</td>
</tr>
<tr>
<td>After RTFOT+PAV</td>
<td>20.34</td>
<td>11.52</td>
<td>9.55</td>
<td>6.33</td>
</tr>
</tbody>
</table>

The results of Table 2 showed that the phase angle δ of asphalt samples decreased in different degrees after aging, especially after PAV aging. It indicated that the proportion of viscoelastic components of asphalt changed significantly after aging, and the proportion of the viscosity part decreased and the elastic component increased significantly. It was further explained that the deformation capacity and stress relaxation ability of the asphalt decreased, that was to say, the low temperature crack resistance dropped. It also can be seen that the composite modulus G* of all asphalt samples has been significantly improved after aging, which indicated that the cementing material of asphalt became brittle and hard, and brittle damage was more prone to happen under the load effect. It can’t be ignored that except matrix asphalt, the difference of the composite modulus and the phase angle of the rest three asphalt samples after PAV aging was not significant, which indicated that the degree of aging of them was quite close and this may be caused by the catalytic aging of recycled asphalt.

CONCLUSIONS

(1) The effect of RTFOT aging on the stiffness modulus and creep rate of all asphalt samples are not obvious, while those of PAV aging are significant;
(2) The stiffness modulus, creep rate, phase angle, loss modulus and other technical indicators of old and new asphalt mixture and recycled asphalt undergone significant changes after RTFOT and PAV aging successively, with the increase of
the amount of recycled asphalt, the technical indicators are more close to the pure recycled asphalt;

(3) Combined with the above test results and the relevant aging theory of polymer materials, it is concluded that the aging process of old asphalt may have a catalytic effect on the aging process of matrix asphalt.

REFERENCES