Study of the property of High Viscosity Asphalt Used in Permeable Friction Course

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Abstract. In order to evaluate the property of self-modified high viscosity asphalt (SHVA), we use GC SBS modified asphalt (GC) and TPS high viscosity asphalt (TPS) as control group. The rolling thin film oven test (RTFOT) and pressure aging vessel (PAV) were adopted to evaluate the aging property of high viscosity asphalts. And the storage stability of SHVA was measured. The results show that after RTFOT, the ductility, zero shear viscosity, viscosity toughness and toughness of SHVA are better than those of GC and TPS. The Zero shear viscosity of SHVA can still reach 19638 Pa·s after PAV. Therefore, the anti-aging performance of SHVA is better than GC and TPS. After heat storage for 72h, the softening point difference of SHVA is 2.3 °C which can meet the storage stability requirement.

1. Introduction
Permeable Friction Course (PFC) also called Open-graded Friction Course or Porous Asphalt (PA) characterized by the large air voids in the mixture which can allows surface water to drain thought its structure so as to reduce the splash and spray as well as the risks of hydroplane and wet skidding so as to enhance the driving safety in the wet weather[1-2]. Additional PFC also has the advantages of improve the riding quality and noise reduction effectiveness. However, Because of the large voids in PFC give rise to the asphalt binder more vulnerable to the air, the sun, the rain and other negative factors, rapid declines of the binder soon cause the early damage of PFC such as loosen and stripping. So, high viscosity asphalt is often used in PFC to enhance the bonding property of the mixture. In the previous study the material component of self-modified asphalt high viscosity asphalt (SHVA) is developed. This paper is aiming to comparatively evaluate the property of SHVA.

2. Experimental

2.1. Materials
GC SBS modified asphalt used in the test is commercial product. TPS high viscosity asphalt (TPS) mentioned in the paper is composed of Shell70⁰ (Shell Ltd, China) and TPS modifier (Taiyu Ltd, Japan) and the dosage of TPS modifier 12%. Self-modified high viscosity asphalt (SHVA) consists of SK70⁰ (SK Ltd, Korean), polymer, compatilizer and stabilizer. The dosage of polymer, compatilizer and stabilizer is 7%, 3% and 0.2% respectively[3-4]. All the modifiers used in SHVA are commercial products. Table 1 shows the basic technical indexes of the asphalts.
Tab1. Basic technical indexes of asphalts

| Test Items                        | GC   | TPS  | SHA  |
|-----------------------------------|------|------|------|
| Penetration(25℃)/0.1mm            | 73.2 | 40.1 | 53.4 |
| Ductility(5cm/min,5℃)/cm          | 38.6 | 35.6 | 42.3 |
| Softening point/℃                 | 74.3 | 90.8 | 92.3 |
| Toughness and tenacity/(N·m)      | 15.1 | 30.6 | 35.7 |
| Toughness/(N·m)                   | 6.8  | 20.2 | 24.9 |
| Zero shear Viscosity(60℃)/(Pa·s)  | 3246 | 19436| 33468|
| Brookfield viscosity(135℃)/(Pa·s) | 1.9  | 2.3  | 2.4  |
| Flashing point/℃                  | 231  | 244  | 252  |
| Solubility/%                      | 99.41| 99.58| 99.46|
| Elastic recovery/%                | 91.0 | 95.4 | 98.3 |

2.2 Methods
ASTM D5801 standard was followed during the toughness and tenacity test. RTFOT and PAV test was performed according to ASTM D-2872 and ASTMD-6521. The Zero Shear viscosity (ZSV) were measured by shear rate sweeping test with dynamic shear rheometer. The storage stability test was performed according to JTG E20-2011.

3. Result and discussion

3.1 Aging property

Tab2. Tests result after RTFOT

| Indicator                        | Penetration (25℃)/0.1mm | Ductility(5cm/min,5℃)/cm | ZSV (60℃)/(Pa·s) | Toughness and tenacity/(N·m) | Toughness/(N·m) |
|----------------------------------|-------------------------|--------------------------|------------------|-------------------------------|-----------------|
| Asphalt Type                     | GC                       | TPS                      | SHV A            | GC                            | TPS             |
| GC                               | 65.4                     | 26.5                     | 2098             | 18.3                          | 7.4             |
| TPS                              | 36.5                     | 20.5                     | 11256            | 32.4                          | 20.8            |
| SHVA                             | 47.2                     | 34.3                     | 26457            | 35.9                          | 25.3            |

It can be seen from Table1 that the performance of the three asphalts before aging is significantly different. The softening point of GC is 74.3℃, and the softening points of TPS and SHVA are all greater than 90℃. The ductility sequence of the three asphalt is SHV A>GC>TPS, which shows SHVA had better low temperature performance. The ZSV of the three asphalt has the largest difference. The ZSV of TPS and SHVA is 6 times and 10 times than that of GC respectively. The ZSV of SHVA is as high as 33468Pa·s, showing good viscosity characteristics. The viscosity and toughness of GC is much smaller than that of TPS and SHVA, indicating that the impact resistance and grip strength of GC are lower, and the bonding performance is weaker than TPS and SHVA.

It can be seen from Table2 that after RTFOT, except the softening point the other indicators of the three asphalts showed different degrees of decline. RTFOT changes the internal structure of asphalt, and the asphalt becomes hard, resulting in the decline of penetration, ductility, viscosity of the three asphalts. The penetration of GC, TPS and SHVA decreased by 10.6%, 8.9% and 11.6% respectively. The effect of RTFOT on the ductility is very obvious. After RTFOT, the decline degree of TPS is the highest, which is 42.4%, followed by GC, which is 31.3%, and the attenuation of SHVA is the smallest, which is 18.9%. RTFOT increases the proportion of viscous components in the asphalt, so the viscosity and toughness of each asphalt are slightly increased. On the whole, the ductility, ZSV, viscosity toughness and toughness of SHVA after RTFOT are better than GC and TPS, and the short-term aging resistance is optimal.
Tab3. Test result after PAV

| Indicator                  | Asphalt Type | Penetration (25℃)/0.1mm | Ductility (5cm/min,10℃)/cm | toughness and tenacity/(N·m) |
|----------------------------|--------------|--------------------------|-----------------------------|-----------------------------|
|                            | SBS          | 47.4                     | 15.7                        | 3477                        |
|                            | TPS          | 24.2                     | 9.1                         | 14218                       |
|                            | SHA          | 32.1                     | 16.9                        | 25240                       |

It can be seen from Table 3 that the indicators of the 3 asphalts are greatly reduced after PAV, so the road performance is degraded. Compared with RTFOT the penetration of GC, TPS and SHVA decreased by 39.8%, 33.7% and 27.8% respectively. Research suggested that when the penetration of asphalt decreases less than 3mm, the crack resistance of the pavement will drop sharply and cracks will begin to appear on the pavement[5]. After PAV, the penetrations of GC and SHVA are more than 3mm, and the crack resistance are better than TPS. The 10℃ ductility of the three asphalts after PAV is ranked as SHVA>GC>TPS. It can be seen that the low temperature performance of SHVA is better than GC and TPS. Compared with RTFOT, ZSV of GC, TPS and SHVA also showed a significant decrease which was decreased by 49.5%, 32.0% and 25.8%. Since some molecules of the polymer modifier are decomposed by oxidation and recombined into smaller particles, the substructure of the polymer changes, the fluidity is enhanced, and the viscosity of each asphalt is declined. Compare with GC and TPS SHVA has the lowest ZSV attenuation, and the ZSV can still reach 19638Pa·s after PAV, which shows the anti-aging performance of SHVA is better than GC and TPS.

3.2. Storage stability

Storage stability of modified asphalt is an important aspect to evaluate the properties of modified asphalt[6]. The dosage of modifiers used in high viscosity asphalt is usually larger than that of the ordinary modified asphalt. Therefore, high viscosity asphalt is more prone to segregation. Different storage times of 0h, 6h, 12h, 48h and 72h were adopted to study the segregation property of SHVA, the results are shown in table 3 and figure 1.

Tab4. Effect of storage time on the segregation of SHVA

| Storage time/h | position | 0 | 6 | 12 | 24 | 48 | 72 |
|----------------|----------|---|---|----|----|----|----|
|                | top      | 92.3 | 91.5 | 92.9 | 93.2 | 92.1 | 91.3 |
|                | bottom   | 92.3 | 90.1 | 91.1 | 91.2 | 89.8 | 88.9 |
| Softening point/℃ | D-value | 0 | 1.4 | 1.8 | 2.0 | 2.3 | 2.4 |

Fig 1. The change of Softening point difference with storage time

It can be seen from figure 1 that when the storage time increases from 0h to 6h, the softening point difference of SHVA increases rapidly; when the storage time increases from 6h to 12h, the softening point difference increases slowly.
difference still increases with time, but the growth rate decrease. When the storage time increased from 12h to 48h, though the softening point difference is still increasing, the growth rate is further reduced. When the storage time increased from 48h to 72h, softening point difference of SHVA only increase 0.1 °C, indicates SHVA is basically in a stable state. It can be seen from table 4 that the storage stability of SHVA can meet the specification requirements. In the preparation process of SHVA, the compatibility of base asphalt and modifiers were fully considered. The addition of compatibilizer used in SHVA can promote the swelling of polymer modifier, which is beneficial to the formation of spatial network structure and inhibit the separation of modifier. The stabilizer can chemically stabilize the modified asphalt which contribute to the self-crossing of modifier and promote the formation of the SBS-asphalt graft. The base asphalt, polymer and various additives used in the SHVA are mutually adsorbed, crosslinked and lapped to form a stable network so as to ensuring the storage stability.

4. Conclusion
(1) RTFOT changes the internal structure of asphalt, and the asphalt becomes hard, resulting in the decline of penetration, ductility, viscosity of the three asphalts. RTFOT had the greatest influence on ductility. The ductility of GC, TPS and SHVA was decreased by 31.3%, 42.4% and 18.9% respectively. RTFOT increased the proportion of viscous components of asphalt which cause the viscosity and toughness of each asphalt slightly increased.
(2) After PAV, the penetrations of GC and SHVA are more than 3mm, and the crack resistance are better than TPS. The zero shear viscosity of SHVA can still reach 19638Pa⋅s after PAV. The anti-aging performance is better than GC and TPS.
(3) After heat storage for 72h, the softening point difference of SHVA is 2.3°C, which can meet the storage stability requirement.

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