Study on Properties of Nano Calcium Carbonate and Polyethylene Complex Modified Asphalt

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ABSTRACT: If added 6 percent of polyethylene in domestic asphalt AH-70, the PE modified asphalt can be made; and then added 6 percent of nano calcium carbonate in PE modified asphalt, the NPCC and PE complex modified asphalt can be made. An experimental research has been conducted for regular technical properties and dynamic mechanical properties of polyethylene and NPCC and PE complex modified asphalt. The experimental result of the regular technical properties shows that after the domestic asphalt AH-70 is modified by adding polyethylene, its high-temperature stability, low temperature crack resistance and temperature sensibility have been improved, and these properties have been further improved by adding nano calcium carbonate in PE modified asphalt. The experimental result of dynamic mechanical properties also shows that it is beneficial to improve the high and low temperature properties of PE modifies asphalt by adding nano calcium carbonate.

KEY WORDS: highway; nano calcium carbonate (NPCC); polyethylene (PE); complex modified asphalt; technical properties

INTRODUCTION

Adding PE into asphalt improves high stability, temperature sensibility and durability of asphalt greatly, while no obvious improvements are found in low temperature flexibility and elasticity of asphalt, and the storage stability of PE modified asphalt is poor, which makes the application of PE modified asphalt limited. Adding NPCC into polymer improves mechanical properties and thermal properties of polymer base greatly, which has been applied widely in macromolecular materials industry. In recent years, NPCC modified asphalt has been studied at home and abroad. In order to further improve properties of PE modified asphalt, NPCC is added into PE modified asphalt; this paper studies its regular technical properties and dynamic mechanical properties to probe into the application prospect of NPCC in the modification of asphalt.

1 Raw materials and experimental methods

1.1 Raw materials

Base asphalt: adopting domestic asphalt AH-70 as base asphalt; the main technical properties are showed in Table 1.
Table 1. Main Technical Properties of Base Asphalt.

| Technical Property                                      | Base Asphalt |
|---------------------------------------------------------|--------------|
| Penetration (25°C, 100g, 5s) /1/10mm                   | 72           |
| Penetration index (PI)                                  | -0.951       |
| Ductility(15°C, 5cm/min)/cm                            | 75.2         |
| Softening point /°C                                     | 45.5         |
| Equivalent softening point /°C                         | 47.5         |
| Equivalent breaking point /°C                          | -13.47       |
| After the RTFOT (163°C, 85min)                         |              |
| Quality loss /%                                         | 0.02         |
| Ductility (15°C)/cm                                     | 29.6         |
| Penetration ratio(25°C)/%                               | 63.9         |

NPCC: adopting NPCC produced by Shenzhen Jiufeng New Material Co., Ltd; the main technical indexes are showed as Table 2.

Table 2. Main Technical Indexes of NPCC.

| Appearance                                      | white powder |
|-------------------------------------------------|--------------|
| Proportion g / cm³                              | 2.5~2.6      |
| Average grain diameter(nm)                      | 15~40        |
| Brunauer-Emmett-Teller(BET)m²/g                | 40           |
| Whiteness%≥                                      | 92           |
| Shape of grain                                  | cube         |
| PH                                              | 8.5~9.5      |
| Moisture%≤                                      | 0.5          |
| CaCO₃%(processed)                               | ≥94.5        |

PE: adopting LDPE produced by Beijing Yanshan Petrochemical Complex; the main technical indexes are showed in Table 3.
Table 3. Main Technical Indexes of PE

| Property                                      | Value  |
|----------------------------------------------|--------|
| Melt flow rate (MFR)/[g·(10 min)^(-1)]      | 2.0    |
| Density (23°C) / (g·cm^(-3))                 | 0.9225 |
| Tensile strength /MPa                        | 9.0    |
| Elongation at break /%                       | 500    |

1.2 Preparation method of modified asphalt

After a certain amount of base asphalt is heated to 170°C, 6 percent of PE modifier is added into it; the asphalt should be stirred manually for 10 minutes, and then the high-shear mulser should be turned on; when the temperature reaches 170-180°C, the asphalt should be sheared continuously for 10 minutes at the speed of around 5000 r/min; then it should continue to be sheared for one hour at the speed of 2000r/min; then 6 percent of NPCC is added into the asphalt, and the mixed asphalt should be sheared for half an hour at the speed of 4000-6000 r/min; finally the NPCC and PE complex modified asphalt is made. At the same time, the PE modified asphalt without NPCC is made, which forms a contrast experiment.

1.3 The experimental method of dynamic mechanical properties of modified asphalt

Compared with such traditional methods as penetration and softening point, the dynamic mechanical properties of modified asphalt tends to conform to viscoelastic behaviors of the materials under the condition of use, and the properties are more applicable to predicting pavement performance of asphalt. The project uses the DMTA-V instrument produced by American Scientific Rheological Company to conduct an experiment about dynamic mechanical properties on NPCC and PE complex modified asphalt sample; the loading mode is single cantilever beam model; the vibrational frequency is 1Hz; the heating rate is 3°C/min; the experimental temperature is -30~30°C.

2 Technical properties of modified asphalt

2.1 Regular technical properties

In accordance with methods in JTG E20-2011 Standard Test Methods of “Bitumen and Bituminous Mixtures for Highway Engineering test procedures”, the main technical properties of PE modified asphalt and NPCC & PE complex modified asphalt have been tested; the result is showed as Table 4.
Table 4. Main technical properties of complex modified asphalt.

| Technical property                          | Base asphalt | Base asphalt+6% PE | Base asphalt+6% PE+6% NPCC |
|---------------------------------------------|-------------|--------------------|----------------------------|
| penetration (25℃, 100g, 5s) /1/10mm        | 72          | 66                 | 56                         |
| Penetration index (PI)                      | -0.951      | -0.189             | 0.691                      |
| Ductility(15℃,5cm/min) /cm                 | 75.2        | —                  | —                          |
| Softening point /℃                          | 45.5        | 57.4               | 59.4                       |
| Equivalent softening point /℃              | 47.5        | 56.3               | 62.0                       |
| Equivalent breaking point /℃                | -13.47      | -12.33             | -16.14                     |
| Quality loss /%                             | 0.02        | 0.11               | 0.66                       |
| Ductility (15℃) /cm                        | 29.6        | —                  | —                          |
| Penetration ratio (25℃) /%                  | 63.9        | 74.5               | 76.4                       |

Table 4 shows that after the domestic asphalt AH-70 is modified by PE and NPCC & PE complex, the softening point rises and the penetration falls which indicates that the high temperature stability is improved; the equivalent softening point rises and the equivalent breaking point falls, which indicates that the high temperature stability and low temperature crack resistance are both improved; the penetration index rises, indicating that temperature sensibility falls.

2.2 The dynamic mechanical properties of modified asphalt

An experiment about dynamic mechanical properties has been conducted on PE modified asphalt and NPCC & PE complex modified asphalt samples respectively. Figure 1 and figure 2 show relation curves between dynamic storage modulus $E'$ and temperature and between loss tangent (tan δ) and temperature respectively.
Figure 1. Relation curve between dynamic storage modulus $E'$ and temperature.

Figure 1 shows that at the range of -30-30°C, the dynamic storage modulus $E'$ of complex modified asphalt and PE modified asphalt fall as the temperature rises; the variation trends of both are similar. The dynamic storage modulus $E'$ of complex modified asphalt is weaker than that of PE modified asphalt, which indicates that the NPCC added into asphalt reduces the stiffness of PE modified asphalt and improves the flexibility of PE modified asphalt.

Figure 2. Relation curve between loss factor tan $\delta$ and temperature.

Figure 2 shows that the loss factor tan $\delta$ of complex modified asphalt is smaller than that of PE modified asphalt if the temperature is lower than below 17°C, but is bigger than that of PE modified asphalt if it's above 17°C, which indicates that the stickiness of complex modified asphalt increases slightly above 17°C while its elastic stiffness increases below 17°C.
CONCLUSIONS

After the domestic asphalt AH-70 is modified by PE and NPCC & PE complex, its softening point rises and the penetration falls; the equivalent softening point rises and the equivalent breaking point falls; the penetration index rises. All these shows that the temperature stability, low temperature crack resistance and temperature sensibility of asphalt have been improved after being modified.

The dynamic storage modulus $E'$ of NPCC & PE complex modified asphalt is weaker than that of PE modified asphalt; the loss factor $\tan \delta$ of complex modified asphalt is less than that of PE modified asphalt below about 17°C but is more than that of PE modified asphalt above 17°C. The result of the experiment about dynamic mechanical properties shows that the NPCC added into asphalt reduces the stiffness of PE modified asphalt, improves the flexibility of PE modified asphalt and helps improve high and low temperature properties of PE modified asphalt.

REFERENCES

Yang, J. (2007). “Polymer Modified Asphalt.” Beijing: Chemical Industry Press.
Yang, X.W. and Liu, K. and Yang D.T. (2008). “Several Problems about PE Modified Asphalt.” Journal of China and Foreign Highway, Dec. 28(6): 203-207.
Xu, S.Z. and Sun, J.B. and Tian, Y.L. (2006). “The Theoretic Analysis and Experimental Study on PE Modified Asphalt.” West-China Exploration Engineering, Jun. 18 (6):189-191.
Guo, M.L. (2002). “The Dynamic Mechanical Thermal Analysis of High Polymer and Composites.” Beijing: Chemical Industry Press.
Liu, D.L. and Yao H.B. and Bao, S.Y (2007). “Performance of nano calcium carbonate and SBS compound modified asphalt.” J. Cent. South Univ. (Science and Technology), Jun. 38(3):579-582.
Zhang, R.H. and Zeng, Z.H. and LI, Y. (2010). “Research on Performance of Composite Modified Asphalt with Nano Calcium Carbonate and Rubber Powder.” New building materials, May 37(5): 63-65.
Yao, H. and Li, L. et al (2011). “Mechanics Performance Research and Microstructure Analysis of Nano materials Modified Asphalt.” Journal of Building Materials, Oct. 14(5): 712-717.
Sun, L. and Zhu, H.R. and Xin, X.T. et al (2013). “Preparation of Nano modified Asphalt and Its Road Performance Evaluation.” China Journal of Highway and Transport, Jan. 26(1):15-22.
Sun, L. and Gu, W.J. and Xin, X.T. et al (2012). “Performance of Nano material Modified Asphalt as Paving Materials.” Journal of the Chinese Ceramic Society, August 40(8):1095-1101.
Zhang, Y.L. and Li, C.D. and Zhang, G.S. et al (2002). “Nanotechnology and plastics.” Beijing: China Light Industry Publishing Press.