Research Article

Preparation and Performance of Asphalt Compound Modified with Waste Crumb Rubber and Waste Polyethylene

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Three kinds of modified asphalt were prepared by adding waste crumb rubber (WCR), waste polyethylene (WPE), and WCR/WPE to base asphalt, respectively. The influence of different doses on the performance of modified asphalt, such as 25°C penetration, softening point, 5°C ductility, and 135°C, 165°C viscosity, was studied, and the modification mechanism of modified asphalt was discussed through the fluorescence microscope. As the waterproofing materials, the waterproofness of WCR/WPE compound modified asphalt was tested. The results show that the WPE modified asphalt has excellent resistance to high temperature and WCR modified asphalt has good low temperature resistance. The resistance to deformation ability of WPE modified asphalt is better than that of the WCR modified asphalt. The 135°C viscosity of compound modified asphalt is better than that of WPE and WCR modified asphalt. In addition, the waterproofness of compound modified asphalt using waterproofing materials is better than that of common waterproofing materials.

1. Introduction

With the rapid development of the automobile industry and packaging plastic industry, the quantity of the waste tires and waste plastics is increasing. For instance, 233 million tons of waste tires was produced in China in 2009, and now waste tires production has more than three hundred million tons. In addition, more than 5 million tons of waste plastics is produced every year in China. General handling method for these solid wastes, such as incineration and landfill, is very serious to the environment pollution. Therefore, it is important to recycle the waste rubber and plastic materials to reduce the environmental pollution, including eliminating black pollution caused by waste tires and white pollution caused by waste plastics [1–5].

By adding the polymer to the base asphalt, it can improve the performance of the asphalt according to the previous reports [6–9]. It not only has good durability, abrasion resistance, and resistance to cracking deformation using modified asphalt pavement, but also can keep good stability

in high temperature or low temperature performance [10–19]. So, it attracts the researchers' interest in modifying the asphalt using the waste materials modifier. In addition, modified asphalt waterproofing materials have an excellent imperviousness; therefore, it has more and more applications in building waterproofing material industry [20–23].

The performance of asphalt can be improved by using single polymer modifier, and then the performance of modified asphalt may be better by using compound modification method. Therefore, we use waste rubber powder, WPE, and waste rubber powder/WPE as the modifier to prepare modified asphalt, and the performance of the modified asphalt is studied in this paper.

2. Experimental

2.1. Materials. The base asphalt was obtained from Shaanxi Guochuang Asphalt Material Co., Ltd. Its physical properties were shown in Table 1.

TABLE 1: The properties of base asphalt.

Properties	Value
Softening point (ring-and-ball apparatus)/°C	51.25
Ductility/cm	>100
Penetration (25°C, 100 g)/0.1 mm	86.13
Viscosity (135°C)/Pa·s	455
Viscosity (165°C)/Pa·s	125

The WPE was obtained from flexible milk packaging bags which has been recycled and disposed. WCR was obtained from waste rubber tire that has been crushed to 30–40 mesh.

2.2. Sample Preparation

2.2.1. The Preparation of Modified Asphalt. According to different experiment conditions, variable power electric furnace was used to heat the base asphalt to 160°C. When single modifier modified asphalt was prepared, WPE or WCR was first put in asphalt with artificial mixing for 30 min and then continued to be mixed for 30 to 90 min using variable speed shearing mixer with a speed rate of 3700 rpm according to the content of modifier.

During the preparation of compound modified asphalt, WPE was first put in asphalt with artificial mixing for 30 minutes and then continued to be mixed for 60 min using a variable speed shearing mixer mixing at a stirring speed of 3700 rpm. The mixture was cooled to about 120°C holding for 30 min for fully swelling WPE; then WCR was added to the mixture to stir for 60 min until WPE and WCR evenly were dispersed in the asphalt. The modifier proportions in modified asphalt were shown in Tables 2 and S1 (see Supporting Information available online at <http://dx.doi.org/10.1155/2016/5803709>).

2.2.2. The Preparation of Waterproofing Materials. Adding 35 wt% talcum powder to the compound modified asphalt at 120°C, the mixture was mixed for 30 min at a speed rate of 3700 rpm. Waterproofing materials were obtained after the mixture was cooled to room temperature.

2.3. Characterization

2.3.1. Physical Properties Test. The physical properties of asphalt, including softening point, penetration, and ductility (5°C), were tested in accordance with ASTM D36 (ring-and-ball apparatus), Chinese specification GB/T 4509 and GB/T 4508, respectively [24].

2.3.2. Viscosity Test. The viscosity of asphalt was tested with the Brookfield rotary viscosimeter in accordance with ASTM D4402 [25].

2.3.3. Watertightness Test. The watertightness of the asphalt waterproof was tested by using the waterproof coiled material impervious instrument DTS-III in accordance with GB/T328.10-2007.

TABLE 2: Modifier proportions in modified asphalt.

Sample number	Modifier proportion
1	1 wt% WCR
2	2 wt% WCR
3	3 wt% WCR
4	4 wt% WCR
5	5 wt% WCR
6	6 wt% WCR
7	7 wt% WCR
8	8 wt% WCR
9	1 wt% WPE
10	2 wt% WPE
11	3 wt% WPE
12	4 wt% WPE
13	5 wt% WPE
14	6 wt% WPE
15	7 wt% WPE
16	8 wt% WPE
17	4 wt% WPE + 1 wt% WCR
18	4 wt% WPE + 2 wt% WCR
19	4 wt% WPE + 3 wt% WCR
20	4 wt% WPE + 4 wt% WCR
21	4 wt% WPE + 5 wt% WCR
22	4 wt% WPE + 6 wt% WCR
23	4 wt% WPE + 7 wt% WCR
24	4 wt% WPE + 8 wt% WCR

3. Results and Discussion

3.1. High Temperature Fluidity. As shown in Figures 1 and S1 (in Supporting Information), the softening point value of asphalt modified with WPE is significantly higher than that of the base asphalt, and the change of the softening point of asphalt modified with WCR is not obvious. With the increase of the modifier content, the high temperature stability is constantly improved. When the content of WPE is 4 wt%, the growth rate of softening point was increased significantly. The high temperature stability of compound modified asphalt is improved obviously, which is better than the asphalt modified with WCR and higher than the 4 wt% content of WPE modified asphalt. With the increase of WCR content, the softening point of compound modified asphalt becomes higher (except the content of 3 wt% WPE), which means the high temperature stability of the asphalt is excellent and can satisfy the requirement of road asphalt.

3.2. Low Temperature Fluidity. As shown in Figures 2 and S2 (in Supporting Information), the ductility of the asphalt modified with WPE is poor, especially when the content of WPE is higher than 4 wt%, which means it has poor plasticity and low temperature cracking resistance. Considering the softening point and ductility of asphalt modified with WPE, 4 wt% WPE was chosen to prepare the modified asphalt. The chosen content of WPE is different from the researches of

FIGURE 1: The softening point of modified asphalt.

FIGURE 3: The penetration of modified asphalt at 25°C.

FIGURE 2: The ductility of modified asphalt at 5°C.

Colbert and You [10] and Zhang et al. [11]. On the contrary, the asphalt modified with WCR has good ductility. The ductility of compound modified asphalt was higher than the asphalt modified with WPE, so its low temperature cracking resistance is significantly superior to WPE modified asphalt. The compound modified asphalt ductility is obvious ups and downs with the increase of WCR. When the WCR content in the compound powder is 3 wt%, the maximum ductility appears at 64 cm and the low temperature cracking resistance is the best.

3.3. The Normal Temperature Fluidity. As shown in Figures 3 and S3 (in Supporting Information), the penetration

of asphalt modified with WCR and WPE decreases with the increase of the modifier dosage, and the resistance to deformation of the asphalt was enhanced. In addition, the penetration of the asphalt modified with WPE is lower than that modified with WCR, which means the resistance to deformation of the asphalt modified with WPE is better than that modified with WCR. With the increase of modifier dosage, the range of the compound modified asphalt penetration is narrow, and the maximum and the minimum appear at 5.63 mm and 4.61 mm, respectively, which is comparable to the penetration (5.56 mm) of 4 wt% content WPE modified asphalt. When the waste rubber powder content in compound modified asphalt is less than 4 wt%, its penetration is less than the asphalt modified with single modifier, which means the ability to resist shear deformation is stable. This result is consistent with the low temperature fluidity of modified asphalt, and the low temperature cracking resistance is the best when the WCR content in the compound powder is 3 wt%. So the chosen content of WCR is different from the results of [12, 13].

3.4. The Viscosity of Modified Asphalt. Viscosity of base asphalt at 135°C and 165°C is 455 Pa·s and 125 Pa·s, respectively, and it can be found that modified asphalt has higher viscosity than the base asphalt (as shown in Figure 4, Figure S4, Figure 5, and Figure S5). At 135°C, with the increase of the modifier dosage, the viscosity of asphalt modified with WCR has no significant change; that is to say, it has no obvious effect on base asphalt. On the other hand, the viscosity of asphalt modified with WPE gradually rises with the increase of modifier dosage. The viscosity of compound modified asphalt increases significantly, and its improved degree is superior to the asphalt modified with single modifier. Due to the fact that the high temperature viscosity reflects the high temperature resistance, the high temperature resistance of compound modified asphalt is the best.

FIGURE 4: The viscosity of modified asphalt at 135°C.

FIGURE 5: The viscosity of modified asphalt at 165°C.

As shown in Figures 4, S4, 5, and S5, modified asphalt viscosity at 165°C is lower than that at 135°C; this is because the internal resistance in the asphalt reduces with the increase of the temperature in high temperature stage, which makes the asphalt shift from viscous body to a liquid. And at 165°C, with the increase of the modifier, asphalt viscosity shows approximate change of that at 135°C. The viscosity shows the resistance to flow; therefore, the rheological properties of the compound modified asphalt at high temperature are superior to the single modified asphalt.

3.5. Morphology Analysis. As shown in Figure 6, the interaction between WCR (or WPE) and base asphalt is not

TABLE 3: Water proofing property of different modified asphalt waterproofing materials.

Number	1#	2#	3#	4#	5#	6#	7#	8#
Permeable? (Y/N)	N	N	N	N	N	N	N	N

chemical change, but partly dissolving and swelling on the volume. WPE and WCR have been labeled in the fluorescence microscope pictures. As shown in Figure 6(a), WPE has a good compatibility and dispersity, which shows the shape of wire mesh. WPE presents a linear polymer property at high temperature, and the mutual infiltration and adsorption happen between two ingredients under the action of light component in the asphalt, coupling with the good spatial three-dimensional network structure of WPE. These results make the high temperature performance of the asphalt significantly improved. From Figure 6(b), it can be seen that WCR exists in the form of a bright spot, and it disperses in base asphalt homogeneously. Rubber powder adsorbs the aromatic oil from the asphalt onto the polymer chain of rubber powder. As a result, WCR and base asphalt get close to each other due to the aggregation, and part of them form the crosslinking structure or a network structure. As we see from Figure 6(c), compound modified asphalt belongs to physical modification, and the rubber phase disperses in the asphalt as a shape of “island.”

3.6. Watertightness of Waterproofing Materials. Asphalt waterproofing materials tested the water proofing property with a waterproof coiled material impervious instrument under the pressure of 0.3 MPa for 30 min, and the result was shown in Table 3.

As we can see from Table 3, the waterproofing materials have no floods occurring phenomenon in the experiment; that is to say, its water proofing property is good and can satisfy the requirement.

4. Conclusions

In this paper, the effects of adding different modifier on softening point, penetration, ductility (5°C), and viscosity of modified asphalt were investigated. In addition, we use the compound modified asphalt to prepare waterproofing materials. The result reveals that WPE modified asphalt has excellent resistance to high temperature and WCR modified asphalt has excellent low temperature resistance. The resistance to deformation of WPE modified asphalt is better than that of WCR modified asphalt. The 135°C viscosity of compound modified asphalt is better than that of WPE and WCR modified asphalt. In addition, the waterproofness of waterproofing materials made by compound modified asphalt is excellent.

Competing Interests

The authors declare that they have no competing interests.

FIGURE 6: Fluorescence microscope pictures of modified asphalt: (a) asphalt modified by 4 wt% WPE, (b) asphalt modified by 3 wt% WCR, and (c) asphalt modified by 4 wt% WPE + 3 wt% WCR.

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