Effect of EVA Dosage and Type on the Properties of High Dose Desulfurized Rubber Modified Asphalt

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Abstract Conventional rubber powder modified asphalt is widely used, but there are drawbacks such as high viscosity, processing difficulties, and poor storage stability, which are avoided by using desulfurized rubber powder. In this study, waste desulfurized rubber powder (DRP) and ethylene vinyl acetate copolymer (EVA) were used as asphalt modifiers. The performance of composite modified asphalt with different VA content and EVA dosage was investigated. It was concluded that the high temperature performance of EVA-1 was superior to EVA-3, but the low temperature effect was average. The modified asphalt prepared with EVA-3 was better suited for cold weather, and the modified asphalt prepared with EVA-2 exhibited good performance in both high and low temperature plasticity, making it suitable for cold weather conditions. good low-temperature plasticity, can improve the physical properties of waste rubber modified asphalt, suitable for conventional asphalt pavement.

1. Introduction

The influence of global warming, extreme weather, and increased traffic loads have made traditional asphalt pavements unable to meet the demands of heavy loads and severe conditions. Therefore, the use of polymers, rubber, inorganic materials, resins[1], and other materials and asphalt through the blending of the preparation of modified asphalt can be a good response to the needs of different environments of the pavement, through the characteristics of the material itself can be for the asphalt to bring a single or multi-faceted performance enhancement. With the rapid development of the economy, cars, trucks, and other means of transportation purchases increased year by year, and a large number of waste rubber tires were produced, resulting in "black pollution" becoming a global problem. The waste rubber crushed or cut into rubber particles or rubber powder for modified asphalt has become one of the focus of research in recent decades, the reuse of waste rubber also plays a

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role in environmental protection.

Studies have shown that modified asphalt prepared using waste rubber has excellent high-temperature performance[2], durability[3], low-temperature cracking resistance, fatigue resistance, and other properties[4], the paved pavement reduces traffic noise as well as the cost of production and maintenance[5-7]. However, with the depth of research, rubber asphalt is found to have viscosity, processing difficulty, and other shortcomings[8], attributed to the rubber internal network structure having been cross-linked, resulting in rubber and asphalt contact areas being small, and poor compatibility. Through the desulfurization process, the rubber's internal cross-linking bonds (such as C-S, S-S), increase the surface active groups and enhance the contact area with asphalt[9]. The majority of current research on desulfurized rubber powder focuses on blending with SBS, while research on high blending with EVA, a thermoplastic polymer, is less common. The VA content of EVA affects its mechanical properties and compatibility with asphalt, which can be improved by increasing the branched chain polarity and reducing crystallinity. Compared to SBS, EVA exhibits more selectivity and is inexpensive. This paper aims to prepare composite modified asphalt by selecting different VA contents and dosages of EVA and desulfurization rubber powder (DRP) to investigate the effects of EVA dosage and structure on the properties of high dosage DRP modified asphalt.

2. Materials and testing methods

2.1. Material Preparation

This study utilized Zhenhai 90 road asphalt as the asphalt raw material. Three different EVA samples were purchased from Aladdin Co., Ltd, each with VA contents of 18%, 28%, and 40%, respectively; and the waste rubber powder was the 40-mesh desulfurization rubber powder produced by Gansu Road and Bridge Shanjian Science and Technology Co. The characteristic parameters of the raw materials are shown in Table 1, Table 2, and Table 3.

Table 1. Performance of the fundamental asphalt.

Items	Test Temperature (°C)	Value	Test Method
Penetration (0.1 mm)	26	83	T 0604—2011
Softening point (°C)	-	47	T 0606—2011
Ductility (cm)	14	180	T 0605—2011
Density(g/cm^3)	15	1.030	T 0603—2011

Table 2. Performance of EVA

VA Content (%)	Density (25 ◦C)/(g·cm^{-3})	Melting point/°C	Melt Index (dg/min)
18	0.94	85	400
28	0.95	70	150
40	0.96	75	60

Table 3. Performance of DRP

Items	Value	Requirements
Heating loss (80°C) (%)	0.6	≤1.5
Ash (%)	7.4	≤8
Acetone extract (%)	17.7	≤20
Mooney viscosity ML 100°C (1 + 4)	32	≤45
Carbon black content (%)	26.2	≥18
Rubber hydrocarbon content (%)	46	≥40
Iron content (%)	0.028	≤0.03
Particle size (mm)	5	≤10

2.2. Preparation of modified bitumen

In this study, modified asphalt was prepared by using externally blended modifiers for both modifiers. Initially, the base bitumen was heated to 160±5°C, and then desulphurized rubber powder was added in batches at varying dosages with manual mixing to prevent buildup. The asphalt was subjected to shear at 1000 r/min for 5 minutes and then at 4500 r/min for 15 minutes after being heated to 180-190°C. The speed was kept constant by using different dosages of EVA. This process was repeated for 20 minutes. Finally, DR/EVACMA was prepared. The ratios of EVA and adhesive powder are shown in Table 4. The performance of single doped desulfurized rubber powder modified asphalt with 20% and 24% dosage is shown in Table 5.

Table 4. Ratios of DRP and EVA

VA content	EVA	DRP	Sample number
18%	2%	20%	Sample 1
18%	2%	24%	Sample 2
18%	6%	20%	Sample 3
18%	6%	24%	Sample 4
28%	2%	20%	Sample 5
28%	2%	24%	Sample 6
28%	6%	20%	Sample 7
28%	6%	24%	Sample 8
40%	2%	20%	Sample 9
40%	2%	24%	Sample 10
40%	6%	20%	Sample 11
40%	6%	24%	Sample 12

Table 5. Physical index of desulfurization powder asphalt

Type of asphalt	Softening point	Ductility	Penetration
20% DRP	55.3	5.7	58.2
24% DRP	56.2	4.8	51.7

2.3. Test Methods

The prepared EVA/Desulfurized Rubber Powder Composite Modified Asphalt was tested in accordance with the Standard Test Methods for Asphalt and Asphalt Mixtures for Highway Construction (JTG E20-2011). Conventional performance tests, including softening point, elongation, and needle penetration, were conducted. The asphalt's rutting resistance was also assessed using temperature scanning with a dynamic shear rheometer (DSR) and FM experiments to examine the phase distribution of modified bitumen.

3. Results and analysis

3.1 General Physics Experiments

The performance of three main indexes of asphalt was tested by 12 sets of prepared samples and the experimental results were analyzed. The conventional physical properties are shown in Figures 1 and 2.

It can be seen from the figure when the gum powder content is certain, the softening point of composite modified asphalt increases with the increase of EVA content, and the ductility and needle penetration decrease with the increase of EVA content. Three different VA content of EVA despite the material structure and mechanical properties of different, will have the effect of improving the softening point of asphalt, the most obvious effect is the EVA-1. Studies have shown that the EVA-1 in the structure of the resin more plastic material, with the increase in the content of elastomer VA, the material from the plasticity of the material began to elasticity, the softening point began to decrease, the EVA-3 has the smallest softening EVA-3 has the smallest softening point. It is worth noting that, in the same EVA dosage, the needle penetration of asphalt with the increase in VA content increases, this is due to the increase in VA polar groups to increase the polarity of the material, improve the dispersion and compatibility in the asphalt, which is also manifested in the viscosity decreases, which represents the shear resistance weakened. The ductility of EVA-3 is the highest at the same EVA dosage, also due to the increase in VA content on the overall polarity of the material and the increase in low temperature plasticity. On the other hand, when the gum powder dosing increases from 20% to 24%, the graph can be visualized that the asphalt viscosity starts to increase and the ductility decreases significantly. This is because when the dosage of rubber powder is too large, it leads to insufficient dissolution of the light components in the asphalt, resulting in buildup, stress concentration, and leading to rapid fracture of the asphalt.

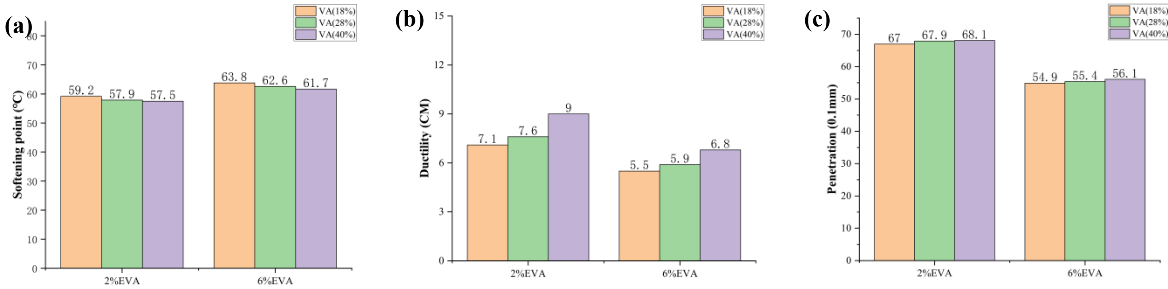


Fig. 1 Conventional Physical Properties of Composite Modified Asphalt with Different EVA Dosage and VA Content at 20% DRP. **(a)** softening point; **(b)** ductility; **(c)** penetration.

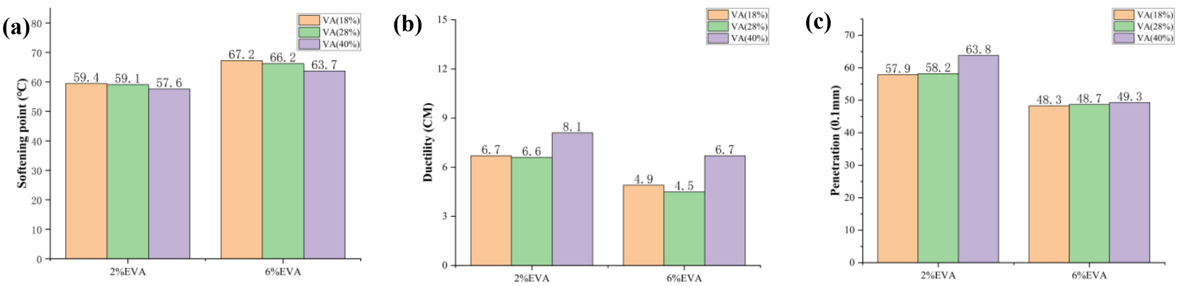
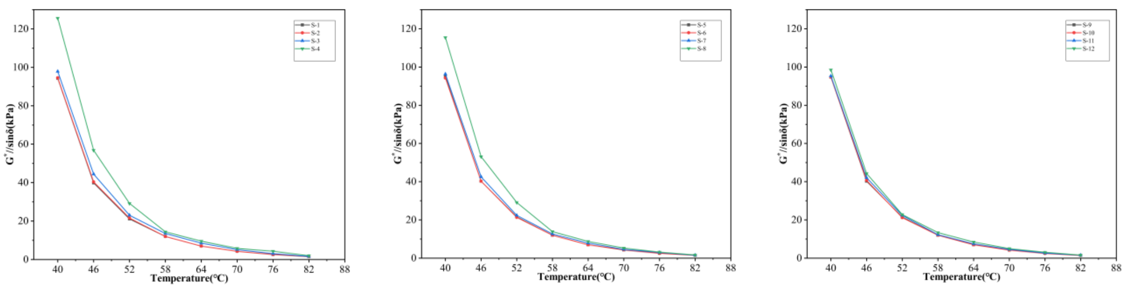


Fig. 2 Conventional Physical Properties of Composite Modified Asphalt with Different EVA Dosage and VA Content at 24% DRP. **(a)** softening point; **(b)** ductility; **(c)** penetration.

3.2 Rheological Experiment

A temperature scan from 40°C to 82°C was used through DSR experiments. The rutting resistance coefficients G*/sinδ of different asphalts were determined and the results are shown in Figure 3.

Regardless of the type of EVA, the rutting resistance coefficient of asphalt, G*/sinδ, increased with increasing dosing, but this effect gradually decreased in effect with increasing VA content. The asphalt prepared with EVA-1 had the highest G*/sinδ, which represents superior medium and high temperature resistance to deformation, and the asphalt prepared with EVA-3, the G*/sinδ did not differ much, even though the increase of the gum powder from 20% to 24%, the increase was also minimal, probably due to the disruption of the internal cross-linking network structure of the desulfurization rubber powder, which led to a decrease in the high temperature performance.



(a) 18%VA（EVA-1） **(b) 28%VA(EVA-2)** **(c) 40%VA(EVA-3)**

Fig. 3 Rheological properties of asphalt with different EVA blends at different VA contents. **(a)**18%VA(EVA-1); **(b)**24%VA(EVA-2); **(c)**40%VA(EVA-3)

3.3.FM Experiment

The fluorescence test clearly shows the distribution of the modifiers in the asphalt, and the composite modified asphalt prepared by three EVAs with 2% doping and 20% DRP was selected for the FM experiment. The results are shown in Figure 4. EVA-1 presents a haphazard distribution compared to the other two EVAs, suggesting that it has not been able to form a continuous phase with the asphalt, while EVA-2 and EVA-3 exhibit a continuous distribution. Thanks to the increase in polarity, this leads to an increase in compatibility with asphalt.

(a) 18%VA（EVA-1） **(b) 28%VA(EVA-2)** **(c) 40%VA(EVA-3)**

Fig. 4 FM Charts.**(a)**18%VA(EVA-1);**(b)**24%VA(EVA-2);**(c)**40%VA(EVA-3).

4. Conclusions

In this study, different types of desulfurized rubber powder/EVA composite modified asphalt were prepared, and conventional physical property tests and microscopic characterization were carried out, and the following conclusions were drawn: different types of EVA have different performance enhancement effects on composite modified asphalt, the incorporation of EVA enhances the medium- and high-temperature rutting resistance of rubberized asphalt; however, with an increase in EVA content, the crystallinity of EVA decreases, reduces the plasticity of the material and The performance of asphalt softening point decreased, increasing the ductility. At the same time, excessive EVA and DRP will make asphalt stress concentration and easy to fracture.FM experiments show that with the increase of EVA polarity, the compatibility with asphalt increases from disordered phase distribution to continuous phase distribution. In this study, it is concluded that the use of high dosage of desulfurized rubber powder blended with EVA for asphalt modification can not only effectively improve the recycling rate of waste tires, but also improve the road performance of asphalt without reducing the storage stability of rubber asphalt. In the future, the asphalt performance can be improved even further by chemically modifying EVA, which can be studied from the perspective of modifier. Also this paper suggests that future research should be carried out on the road performance of rubber powder and EVA modified mixes.

Acknowledgments

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