Effects of preparation process on performance of rubber modified asphalt

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Abstract. The rational utilization of waste rubber tire is essential for the environmental protection. Utilizing rubber particles to modify asphalt can not only improve asphalt performance, but also help the recycling of waste materials. Considering the effect of different preparation process parameters on the performance of rubber modified asphalt, this paper analyzes the effects of the shear temperature, shear time and shear rate on the performance of rubber modified asphalt, and provided a reference for its preparation.

1. Introduction

The increasing traffic load and the more frequent extreme weather conditions put higher requirements on the performance of the road construction materials. In recent years, road damage phenomena such as pavement rut, bleeding and bulling have happened very frequent and become increasingly serious. Therefore, how to improve the performance of asphalt mixture and prolong the service life of pavement becomes an important research direction of the road building materials [1].

The amount of waste rubber tire has been increasing along with the number of cars growing in China. Relevant data show that there are new 250 million waste rubber tires totaling 520 tons in 2010. The existing recycling level of waste rubber tire is low and large numbers of tires are disposed with fire, which has aggravated the environmental pollution. In fact, waste can be turned into treasure as the effective components contained in waste rubber tire can be used for asphalt modification. Studies on rubber modified asphalt have attracted broad attention of scholars all over the world [1, 2].

Waste rubber tire is an ideal asphalt modifier, including natural rubber, synthetic rubber, carbon black and other ingredients. It’s shown in some research papers that adding rubber particles into asphalt can significantly improve the performance of asphalt and its mixture, such as enhancing durability of pavement, increasing the toughness and elasticity recovery of asphalt, improving the aging resistance and anti-rutting ability, and reducing the pavement noise etc. [3, 4].

The process of rubber modified asphalt mainly consists of dry and wet processes, and the wet process has been widely applied in real-world engineering. Considering the effect of different preparation process parameters on the performance of rubber modified asphalt, this paper analyzed the effects of the shear temperature, shear time and shear rate on the performance of the rubber modified asphalt, which provided a reference for its preparation [5-10].

2. Materials

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The 90 # matrix asphalt was selected in the experiment, whose properties were shown in table 1.

The rubber particles used in the experiment were obtained through normal temperature crushing method, and the pass rate of 30 mesh was 69.8%, 40 mesh 33.5% and 50 mesh 20.8%.

| Test properties                        | Unit | Standard requirements | Test results |
|----------------------------------------|------|-----------------------|--------------|
| Penetration (25℃, 100g, 5s)            | 0.1mm| 80~100                | 96           |
| Ductility (15℃)                        | cm   | ≥100                  | >100         |
| Softening point (ring and ball method) | °C   | ≥42                   | 56           |

3. Experimental results and discussion

3.1. Effect of shear temperature on the performance of modified asphalt
The shear temperature will affect the performance of rubber modified asphalt. The low shear temperature will reduce asphalt fluidity and lead to the high consistency of asphalt, which is bad for its adsorption and swelling, while high shear temperature is easy to cause the aging of asphalt. Therefore, shearing temperature was set as a single variable in this experiment to study its effect on the performance of rubber modified asphalt. In this experiment, the dosage of rubber particles was 15%, shear time 45 min, shear rate 5000r/min, swelling time 60 min (180℃) and the shear temperature 150℃, 160℃, 170℃, 180℃ and 190℃. The penetration softening point and ductility at 5℃ index were chosen as evaluation indexes. Test results at different shear temperatures were shown in table 2 and the curve of each parameter with shear temperature was shown in figure 1.

![Figure 1. The curve of each parameter with shear temperature.](image)

The conclusion can be drawn based on the experiment data that the penetration value increases but only in a small extent when the shear temperature increases. The softening point increases with the
shear temperature increasing from 150°C to 180°C and reaches its maximum at 180°C, then decreases with the temperature further increasing. Thus, 180°C could be taken as the optimal shear temperature for softening point index. Ductility shows a significant increase at 5°C index when the shear temperature increases from 150°C to 170°C. However, as the shear temperature continues to increase, the ductility only increases slightly and then decreases. The peak value of ductility shows up at 180°C. Therefore, the range from 170°C to 180°C is chosen to be the optimal shear temperature for ductility at 5°C index.

### 3.2. Effect of shear time on the performance of modified asphalt

The shear time is another important factor contributing to the preparation quality of rubber asphalt. A short shear time would not allow rubber particles to shear adequately, while a long shear time is easy to cause the aging of asphalt. So the shearing time was set as a single variable to study its effect on the performance of modified asphalt in this paper. In this experiment, the dosage of rubber particles was 15%, shear temperature 180°C, shear rate 5000 r/min, swelling time 60min(180°C) and shear time 15 min, 30 min, 45 min and 60 min. The penetration softening point and ductility at 5°C index were chosen as evaluation indexes. The test results at different shear time were shown in table 3 and the curve of each parameter with shear time was shown in figure 2.

| Shear time (min) | Ductility (5°C) | Average Penetration 25°C (100g, 5s, 0.1mm) | Average Softening point (°C) |
|------------------|----------------|---------------------------------|----------------------------|
|                  | 1   | 2   | 3   | 1   | 2   | 3   | 1   | 2   | 3   |
| 15               | 12.23 | 12.15 | 12.13 | 12.17 | 61.9 | 63.2 | 61.8 | 62.3 | 51.8 |
| 30               | 12.24 | 12.35 | 12.19 | 12.26 | 62.3 | 62.3 | 61.1 | 61.9 | 52.6 |
| 45               | 12.62 | 11.80 | 12.54 | 12.32 | 62.7 | 61.5 | 59.2 | 61.1 | 53.1 |
| 60               | 12.19 | 12.41 | 12.33 | 12.31 | 62.5 | 61.8 | 60.5 | 61.6 | 53.1 |

**Figure 2.** The curve of each parameter with shear time.

From the table and the figure it can be concluded that the penetration of rubber modified asphalt has a minimum value when the shear time is 45min, which can be used as the shear time for penetration index at 25°C. The softening point of rubber modified asphalt is relatively stable in the range of 45 min to 60 min, and this eigenvalue interval of the shear time is suitable for softening point index of rubber modified asphalt. The ductility of rubber modified asphalt at 5°C is increasing as the shear time increases from 15min to 45min. The value of ductility at 60 min is close to that at 45min, so that 45 min is chosen as the shearing time for the ductility index at 5°C.

### 3.3. Effect of shear rate on the performance of modified asphalt
The shear rate is another factor with the same importance as shear temperature and shear time in affecting the performance of rubber modified asphalt. The low shear rate will lead to a bad shear result, nevertheless if the shear rate is too high, the temperature of rubber particles will rise rapidly and cause waste of resources. So in this project the shearing rate was set as a single variable in the experiment to study its effect on the performance of modified asphalt. In this experiment, the dosage of rubber particles was 15%, shear temperature 180°C, shear time 45 min, swelling time 60 min (180°C) and shear rate 3000 r/min, 4000 r/min, 5000 r/min, 6000 r/min and 7000 r/min. The penetration softening point and ductility at 5°C were chosen as the evaluation indexes. Test results at different shear rates were listed in table 4 and the curves of each parameter with shear rate were shown in figure 3.

**Table 4. Test results of properties at different shear rate.**

| Shear rate (r/min) | Ductility (5°C) (cm) | Average | Penetration 25°C (100g, 0.1mm) (5s, cm) | Average | Softening point (℃) | Softening (0.1mm) | Average |
|-------------------|---------------------|---------|----------------------------------------|---------|---------------------|---------------------|---------|
|                   | 1       | 2       | 3       | 1 | 2 | 3 | 1 | 2 |     |
| 3000              | 12.22   | 12.18   | 12.23   | 12.21 | 62.1 | 61.4 | 61.9 | 61.8 | 51.8 | 52.4 | 52.1 |
| 4000              | 12.23   | 12.25   | 12.30   | 12.26 | 62.1 | 60.8 | 61.3 | 61.4 | 52.3 | 52.9 | 52.6 |
| 5000              | 12.62   | 11.80   | 12.54   | 12.32 | 62.7 | 61.5 | 59.2 | 61.1 | 53.1 | 53.9 | 53.5 |
| 6000              | 12.31   | 12.34   | 12.28   | 12.31 | 61.2 | 60.8 | 61.6 | 61.2 | 53.4 | 54.0 | 53.7 |
| 7000              | 12.32   | 12.31   | 12.36   | 12.33 | 61.2 | 62.4 | 60.9 | 61.5 | 53.0 | 53.6 | 53.3 |

**Figure 3.** The curve of each parameter with shear rate.

According to experimental data, the following conclusions can be drawn. The penetration of rubber modified asphalt is decreasing until the shear rate reaches 5000 r/min, but the change of penetration rate is only in a small range. The peak value of the softening point appears when the shear rate is in the range of 5000 r/min to 6000 r/min, and such eigenvalue range of shear rate is suitable for the softening point index of rubber modified asphalt. The ductility of rubber modified asphalt at 5°C shows an increasing trend with the increasing shear rate, but the change is not obvious after 5000 r/min, So 5000 r/min is applicable to 5°C ductility index of rubber modified asphalt as shearing rate.

**4. Conclusion**

Considering the effect of different preparation process parameters on the performance of the rubber modified asphalt, this paper selects the shear temperature, shear time and shear rate as the research objects and analyzes the effect of these process parameters on the performance of rubber modified asphalt. From the test results it can be concluded that all preparation process parameters have effects on the performance of the rubber modified asphalt. Comprehensively considering these effects, this paper recommends the shear temperature 180°C, shear time 45 min and shear rate 5000 r/min as the best preparation process parameters for the rubber modified asphalt. The process parameters
determined by the institute in this paper can provide a reference for preparation of the rubber modified asphalt.

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