Effect of waste rubber powder on swelling mechanism of modified asphalt

YANG Sanqiang¹, RUN Mingtao², ZHOU Xiaoyu¹, WANG Lianfang³

(1. School of Building Engineering, Hebei University, Baoding 071002, Hebei, China; +86-18932662692, ysq0999@126.com.
2. Key Laboratory of Medicinal Chemistry and Molecular Diagnostics, Hebei University, Baoding 071002, Hebei, China;
3. Key Laboratory of Highway engineering in special Area, Chang’an University, Xi’an 710061, Shanxi, China)

ABSTRACT

The modification principle of crumb rubber modified asphalt has always been the key research of engineering technicians. By means of thermogravimetric analysis, infrared spectroscopy, SEM scanning, the effect of physicochemical reactions of 70# asphalt mixed with different quantities (20%, 25%, 30%, 35%, and 40%) on the mechanism of the swelling of modified asphalt after high temperature treatment was revealed from microscopic angle. Results show that: Rubber powder have good compatibility with asphalt and it can be distributed evenly in asphalt In addition to a small part of the rubber powder that has reacted chemically, most of the rubber, more than 50% of the rubber powder can exist as its original form.; High temperature causes the rubber powder asphalt modified to generate new chemical matter by oxidation decomposition reaction. The swelling property and stability of modified asphalt will increase with the increase of the amount of rubber powder, but high content of the powder will affect the performance of modified asphalt, which can be improved remarkably by adding special oxidant.

KEYWORDS: road engineering; waste rubber powder; content; modified asphalt; swelling mechanism; microscopic characteristics

0. INTRODUCTION

At present, the development of highway traffic in China is rapidly, rubber modified asphalt pavement as a new kind of road, not only provide a novel method for the treatment of waste tires, but also can greatly improve the performance of asphalt pavement, and therefore get great attention of the industry. Rubber modified asphalt pavement is widely used in the road industry in USA, Japan, Germany and other countries. The content of rubber powder is an important factor that may affect the performance of rubber modified asphalt pavement, the amount of rubber powder is usually controlled by 17~23% in the world, the rubber modified asphalt with high content of powder is not only limited by the manufacturing process, but also the rubber modified asphalt with too high rubber content can not be applied in the actual project because of the high viscosity, poor fluidity and low dynamic modulus.

From the microscopic point of view, the paper makes a comparison analysis of the rubber powder modified asphalt under different rubber powder content, and puts forward
some suggestions for increasing the amount of the rubber powder.

1. TEST EQUIPMENT AND SCHEME

This experiment is mainly aimed at the particle size not less than 40 mesh of rubber powder and 70# asphalt. 70# asphalt is mainly used in the region with high temperature in summer, which has higher requirements for thermal stability and high and low temperature resistance of asphalt.

1.1 Test Equipment

The experiment was carried out under laboratory conditions. By using the Thermogravimetric Analyzer, we can get the percentage of each component of crumb rubber modified asphalt, and analyze the specific chemical reaction of the rubber powder and asphalt from the molecular level by IR analysis. With the introduction of SEM scanning technology, the size and distribution of the colloidal particles and the surface details of the modified asphalt were observed in detail.

1.2 Pilot Scheme

Study on the micro-properties of rubber modified asphalt with different rubber powder content as the independent variable, after the same conditions of high-temperature heat treatment, through the infrared spectrum test and SEM scanning electron microscope to compare the microscopic morphology of the sample.

2. ANALYSIS OF SWELLING OF MODIFIED ASPHALT WITH WASTE RUBBER POWDER

The aging of asphalt is an important factor affecting the performance of asphalt pavement, as the binder of aggregates, in the hot mix, construction and use process by temperature, light, air and precipitation and other environmental factors, such as the impact of vehicle load and the role of volatile, a series of irreversible physical and chemical changes may occur to the asphalt mixture. The laboratory can simulate asphalt aging by heat treatment of bituminous mixtures.

2.1 Analysis of Swelling of Asphalt Modified by Waste Rubber Powder without Heat Treatment

The swelling of the crumb rubber modified asphalt can be obtained by observing the microscopic morphology of the colloidal particles. In the experiment, the samples were treated by etching method and brittle fracture method. Table 1 is a summary of the results obtained by SEM observation of the sample after treatment with etching method.

From table 1, the distribution of the rubber powder in the asphalt is more evenly, with the increase of the amount of the rubber powder, the swelling of the rubber powder and the bitumen increases first and then decreases.

<table>
<thead>
<tr>
<th>Rubber Powder</th>
<th>SEM observation of morphology</th>
</tr>
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<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td>20%</td>
<td>Irregular surface, enlarged to see the distribution of white powder particles on the surface, particle size is generally less than 40 microns below, the distribution is more evenly</td>
</tr>
<tr>
<td>25%</td>
<td>More dense particle distribution, the particle size is about 30 microns below, the distribution is more evenly</td>
</tr>
<tr>
<td>30%</td>
<td>The surface can observe the white particle distribution, the particle size is about 30 microns below, the distribution is relatively uniform</td>
</tr>
<tr>
<td>35%</td>
<td>Dense particle distribution, the particle size is about 40 microns below, the size is different, the distribution is relatively uniform</td>
</tr>
<tr>
<td>40%</td>
<td>Dense particle distribution, the particle size is about 40 microns below, the size is different, the distribution is relatively uniform</td>
</tr>
</tbody>
</table>

Fig. 1 and Fig. 2 are the SEM scanning diagrams of the rubber modified asphalt with 20% waste glue powder, which was treated with brittle fracture method and etching method.

From Fig. 1, the scanning at low magnification, the uniform distribution of white particles can be observed in the brittle section, the size range is 10~200 micron. The uniform distribution of white particles can be observed from Fig. 2 and the particle size is generally below 40 microns.

![Fig 1](image1.png)  ![Fig 2](image2.png)

The reason for the large difference of the size of the colloidal particles observed by the etching method and brittle fracture method may be that the colloidal powder treated by etching is often partially embedded in the asphalt base and cannot be observed completely.

### 2.2 Analysis of Swelling of Asphalt Modified by Waste Rubber Powder after Heat Treatment

(1) Analysis on the change of heating components of asphalt modified by rubber

The change of composition of rubber modified asphalt after heat treatment can be obtained by thermogravimetric analysis, infrared spectroscopy and SEM. Fig. 3 is a thermogravimetric diagram of different rubber powder content modified asphalt at 180 °C high temperature.
From Fig. 3, after 180 °C heat treatment for 2 hours, pure asphalt weightlessness about 6.1%, including 20% rubber powder modified asphalt weightlessness about 4.8%, containing 25~40% rubber powder modified asphalt weightlessness about 3.2~3.6%. The main components of asphalt are saturated, aromatic, colloid, asphaltene, it can be speculated that the main reason for weightlessness is the evaporation of saturated asphalt.

Fig. 4 is the infrared spectra of rubber modified asphalt with 20% rubber powder after 180 °C heat treatment at different time. At the time of the unhandled (0d), the infrared spectra were mainly the absorption vibration peaks of the C-H and the combined Water (1630cm⁻¹), and after the heat treatment 1day, a plurality of absorption vibration peaks appeared on the 1500~1900cm⁻¹ spectra, and the 1600cm⁻¹ represented the benzene ring skeleton vibration peaks, 1,600~ 1900cm⁻¹ these peaks represent the absorption vibration of the carbonyl, indicating that the carbon in the asphalt or rubber powder after heat treatment has been oxidized, and that the IR spectra are similar to those of 1d treatment when the heat treatment 2d~4d, just 1700cm⁻¹,1200cm⁻¹ the peak intensity 2days after the rise, 3d-4d after lowering, It is indicated that when the heat treatment time is 1d-2d, the chemical composition of the modified asphalt is mainly oxidized by weak bond (mainly the unsaturated double bond in the rubber powder). When the heat treatment time 3d-4d, the main is to form carbonyl or ester of carbonyl, decomposition reaction.

Fig. 5 is the infrared spectra of rubber modified asphalt with 25% rubber powder after 180 °C heat treatment at different time. From Fig. 5, it can be found that 25% of rubber modified asphalt in the 1d~2d performance of carbonyl content, 3d~4d appeared the characteristic peak of anhydride, indicating the dehydration condensation between carboxyl, this may be the reason of it’s highest thermal stability.
Fig 4. Infrared Spectrum of Modified Asphalt content with 20% rubber powder. Fig 5. Infrared Spectrum of Modified Asphalt content with 25% rubber powder.

Fig. 6, fig. 7, fig. 8 are the infrared spectras of rubber modified asphalt after 180 °C heat treatment at different time with different rubber powder content of 30%, 35% and 40%.

Fig. 6, when the amount of rubber powder is 30%, 180 °C high-temperature heat treatment, the main performance is carbonyl content increases in the first 2 days, since then it performance for carbonyl reduction.

From Fig. 7, when the amount of rubber powder is 35%, 180 °C high-temperature heat treatment, the processing time is 1d, the main performance is the carbonyl content increased, 2d performance for carbonyl reduction, 3d–4d performance for the carbonyl content increased.

It is shown from fig. 8 that when the amount of rubber powder is 40%, the carbonyl content is increased in the process of 180 °C high-temperature heat treatment.
Fig. 8. Infrared Spectrum of Modified Asphalt content with 40% rubber powder.

The modified asphalt was scanned by SEM electron microscope after 180 °C were treated with 1d, 2d, 3d and 4d respectively. Fig. 9, fig. 10 are 30% rubber powder content of modified asphalt after 1d, 4d heat treatment of the scanning results.

From Fig. 9, the heat treatment of 1d, the surface of the sample is smooth, after the force to form sharp cracks and fragments, indicating that the surface is very brittle, which is related to the evaporation of liquid saturation. The test found that although the surface is very brittle, but the bottom still maintain the flexibility of asphalt, that is, the evaporation of saturation is limited to the surface of the material.

From Fig. 10, the material after heat treatment 4d, in addition to the characteristics of heat treatment of 1d, but also of the sample appeared some small holes on the surface. These holes forms mainly because the volatile gasification of saturated parts and formed the bubbles which cracks on the surface of the sample.

(2) Effect of rubber powder content on modified bitumen

Modified asphalt after heat treatment, in addition to some of the volatile saturation, some of the rubber powder and asphalt chemical reaction, some still in the form of rubber powder, which is called effective rubber powder.

The modified bitumen is dissolved in N-heptane, and the filter cake is dried and the filter cake is mixed with bitumen and rubber powder. The content of the effective rubber powder
was calculated according to the content of asphaltene in the measured asphalt and the amount of weightlessness after soaking, as shown in table 2.

**Table 2 The Relationship Between the Content of Effective Rubber Powder and the Amount of Rubber Powder**

<table>
<thead>
<tr>
<th>Rubber Powder Content</th>
<th>20%</th>
<th>25%</th>
<th>30%</th>
<th>35%</th>
<th>40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective rubber powder Content (%)</td>
<td>16.6</td>
<td>17.3</td>
<td>18.8</td>
<td>20.3</td>
<td>22.5</td>
</tr>
<tr>
<td>The proportion of effective rubber powder to the added powder (%)</td>
<td>83</td>
<td>69.2</td>
<td>62.7</td>
<td>58</td>
<td>56.3</td>
</tr>
</tbody>
</table>

Fig. 11 is the proportion of the amount of rubber powder added to the effective rubber powder.

![Fig 11. Percentage of effective rubber powder in powder incorporation](image)

From table 2 and Fig. 11, the content of effective rubber powder increases with the increase of the amount of rubber powder, but the proportion of effective rubber powder to the total amount of rubber powder decreases gradually.

### 3. CONCLUSION

(1) After the brittle fracture method and etching treatment of modified asphalt can be concluded that the rubber powder mixed with asphalt, only a small part of the chemical reaction, more than 50% of the powder is still in rubber phase.

(2) Through the infrared spectrum experiment, the rubber modified asphalt with different rubber powder content has been analyzed by the changes of the components in the high-temperature heat treatment. The chemical reaction between the rubber powder and the asphalt is characterized by the oxidation of weak bonds, which then forms the carbonyl and decomposition reaction between ester bases and produces new chemical substances.

(3) Analysis of the effective rubber powder content test data it can be known that the content of the effective rubber added in the asphalt increased with the increase of the amount
of rubber powder, but the effective rubber powder accounted for all the proportion of rubber powder with the increase in the amount of rubber powder decreased, and eventually stabilized at about 55%.

(4) According to the change of the particle size of the rubber powder modified asphalt treated by etching method, the particle size of crumb rubber powder increases with the increase of the amount of rubber powder, that is, with the increase of the amount of the powder, the swelling of the modified asphalt increases first and then decreases.

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作者简介
杨三强，（1980-），男，四川绵阳人，河北大学教授、硕士生导师，博士，主要从事道路工程方向。Tel: 18932662692. E-mail: ysq0999@163.com。