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The Influence of Biomass Masut and Emulsifier on Emulsified Bio-asphalt Performance

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ABSTRACT: This study aims to explore and analyze the different influential factors in the process of preparing emulsified bio-asphalt. Colloid Mill was used in this experiment for the process of emulsification with a high speed rotation at 100 ^{o}C. The single factor analysis was adopted in this study to explore the influence of biomass masut and emulsifier on the performance of emulsified bio-asphalt. The experiment set the temperature of 10 ^{o}C, 45~ 50 ^{o}C and 60 ^{o}C , the content of the biomass masut is 10%, 15%, 20%, 25%, 30%, the content of emulsifier is 2.0%, 2.5%, 3.0%, 3.5%, 4.0%, two types of emulsifier named SY-type and MD-type were used in the experiment to compare with the properties of the base asphalt. The remaining amount of evaporation residue of emulsified bio-asphalt on sieve, the penetration, the softening point, the ductility at 10 ^{o}C, the viscosity at 60 ^{o}C, the standard viscosity and the storage stability after 5 days were tested as the indicators to evaluate the performance of the emulsified bio-asphalt. It was found from the experiment that the indicators have a regular curve with the increase of the content of the biomass masut and the emulsifier. The study shows that when the water-oil ratio is 55:45, the content of biomass masut is 15~20%, the content of emulsifier of SY-type is 3.5% and MD-type is 3.0%, the performance of emulsified bio-asphalt plays well, the content is recommended.

KEYWORDS: Emulsified bio-asphalt performance; single factor analysis; biomass masut; emulsifier

INTRODUCTION

In recent years, bio-asphalt as a new road material has attracted wide concerns. Bio-asphalt is a mixture composed of bio-oil and base asphalt, properly mixed under certain conditions. The bio-oil has advantages such as wide distribution, environmental friendliness, and large storage capacity. Compared with petroleum asphalt, the bio-oil has a good application prospect. However, the high oxygen content of bio-oil about 15~30% results in poor thermal stability, and aging resistance, which severely limit the application and promotion of bio-asphalt. If bio-oil is used in common asphalt mixture, it will affect the road construction and road performance. Emulsified asphalt is produced at room temperature, has little influence on the aging properties of asphalt. Thus, if bio-asphalt is used in emulsion, the prepared emulsified bio-asphalt can not only avoid the quick aging which usually occurs in high temperature, but also reduce the usage of neat asphalt.

Through a series of experiments, scholars have found that after adding bio-oil into petroleum asphalt, the prepared bio-asphalt has good road performance (Yang et al., 2013). The content of bio-oil has a great influence on the anti-fatigue properties of bio-asphalt (You et al., 2014). The incorporation of biomass masut can improve the low-temperature performance of bio-asphalt (Liao et al., 2014). The experiment analyzed and summarized the road performance and physical and chemical properties of bio-asphalt binder (Wang et al., 2014) (Cao et al., 2014). At the same time, studies on the evaporation residue of emulsified asphalts have shown that, there is a significant difference in the properties of different evaporation residues at high and moderate temperatures (Bahia et al., 2013). Emulsifiers with different chemical compositions have an influence on the performance of the evaporation residue (Kabir et al., 2014). Researchers have studied the performance of emulsified asphalts and the rutting resistance of residues by DSR (Wasiuddin et al., 2014); Research have found that when the residual water content in the evaporation residue was less than 0.1%, the performance of the evaporation residue can be satisfied (Boysen et al., 2014). Micro-experimental is used for the study and found that the amount of emulsified asphalt plays a great impact on internal voids of mixture (Sha et al., 2013). The rheological behavior of the evaporation residue was greatly affected by the different content of emulsifier (Deng et al., 2014). The research of emulsified bio-asphalt has not been carried out at present and the influence factors of its performance are not clear. So this paper aims to explore the influence factors of properties of bio-asphalt and emulsified asphalt evaporation residue. The contents and composition of emulsified bio-asphalt were analyzed by single factor analysis, to determine the impact of factors as biomass masut and emulsifier on the impact of the performance of emulsified asphalt. In order to enhance the contrast and persuasive of the experiment, MD-type emulsifier and SY-type emulsifier were used for the study.

1 OBJECTIVE AND SCOPE

The emulsification equipment used in this study is a Colloid Mill. The maximum rotating speed of the equipment is 3000rpm, and 2000g emulsified asphalt can be prepared each time. Processed by the high-speed rotation, asphalt is greatly sheared and rubbed. By the high-frequency oscillation and high-speed swirl, the asphalt has been thoroughly emulsified, crushed, and dispersed to form a sort of homogeneous material.

2 MATERIALS AND EXPERIMENT

In this study, the oil to water ratio of the prepared emulsified asphalt was 55:45, and the MD-type and SY-type emulsifiers was used. Both the emulsifiers were cationic, mainly used for slurry seal. The LQ-type surfactant was used in this study, and the calcium chloride and polyvinyl alcohol were used as stabilizers.

The preparation process of emulsified bio-asphalt used in this study is briefly described as follows: The bio-asphalt is heated to 140~150 ^{o}C, then a certain amount of surfactants is added into the asphalt, and stirred 5~10 minutes. The temperature was kept constant, then a certain amount of pure water is heated to 90~100^{o}C and added into the mixture. Calcium chloride and polyvinyl alcohol are then added and stirred evenly, added a weighed emulsifier. Fully dissolved the materials, and finally added the diluted hydrochloric acid to adjust the pH value. Finally the temperature of the soap is maintained above 60^{o}C.

During the configuration of soap, the colloid mill should be preheated with hot water at 80^{o}C. In the emulsification process, the soap solution is firstly added to dissolve in the colloid mill, and then added the bio-asphalt. During pulling the bio-asphalt into the colloid mill, the temperature of bio-asphalt should be kept between 130~140^{o}C. The bio-asphalt should be added stably and slowly. During the whole emulsification process, the bio-asphalt can be added with 4~5 times. After bio-asphalt is all added, further mixing the mixture for 1~2 minutes.

In this study, the preparation of emulsified bio-asphalt was studied by single factor analysis. The main research objects are biomass masut and emulsifier two factors.

3 RESULT AND DISCUSSION

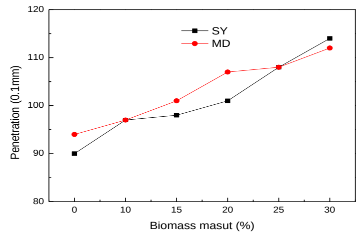
Effect of Content of Biomass Masut on Performance of Emulsified Bio-asphalt

Biomass masut is one of the basic components of the bio-asphalt, and plays an important role in the process of preparation for the emulsified bio-asphalt. Different content of biomass masut had significant impact on the performance of bio-asphalt.

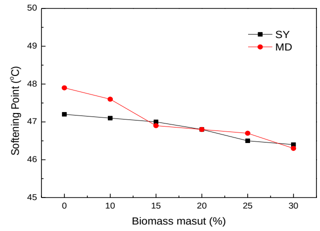
The performance are shown in table 1 and figure 1.

Table 1. The Impact of Different Content of Biomass masut on Emulsified Bio-asphalt.

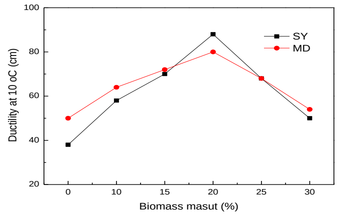
Project	Unit	Base Asphalt	Biomass Masut 10%	15%	20%	25%	30%
SY-type sieve residue	%	0.05	0.05	0.06	0.06	0.07	0.07
MD-type sieve residue	%	0.04	0.04	0.05	0.06	0.06	0.07
Breaking speed		Slow crack					



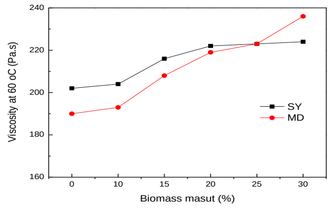
(a) Relationship between biomass masut content and penetration



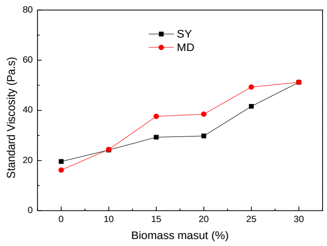
(b) Relationship between biomass masut count and softening point



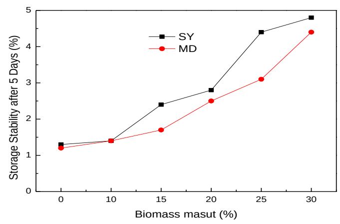
(c) Relationship between biomass masut count and ductility at 10 °C



(d) Relationship between biomass masut count and viscosity at 60 °C



(e) Relationship between biomass masut count and standard viscosity



(f) Relationship between biomass masut count and storage stability after 5 days

Figure 1. Effect of Different content of Biomass masut on Performance of Emulsified Bio-asphalt.

It can be illustrated from Table 1 that the residual amount of the emulsified bio-asphalt on sieve is less than 0.08%, and increased with the increase of the dosage of the biomass masut. It was found from the experiment that the charge of emulsified asphalt was cationic and the breaking speed was slow.

Figure 1 shows the impact of different content of biomass masut on the basic properties of emulsified bio-asphalt.

It can be seen from figure 1(a) that: penetration gradually increased with the increase of biomass masut content. Indicated that the incorporation of biomass masut increased the content of lightweight components in emulsified bio-asphalt, resulted in increased penetration. The higher the content of biomass masut, the more obvious the increase of penetration.

Figure 1(b) shows the relationship between biomass masut and softening point. The softening point of two emulsified bio-asphalt gradually decreased with the increase of biomass masut content, but the magnitude was not significant. Which indicated that with addition the biomass masut, the presence of light components increases, so the softening point decreased.

Figure 1(c) shows the variation of ductility with different contents of biomass masut at 10^{o}C. The ductility of the two emulsified bio-asphalts decreased after first increased with the increased of the content of bio-oil at 10 ^{o}C, and reached maximum at the content of 20%. Which indicated that with the addition of biomass masut, the presence of light components in biomass masut makes the ductility increased at 10^{o}C. However, bio-asphalt plays a more important role in ductility when the amount of biomass masut more than 20%, so the trend of the ductility at 10^{o}C was declined.

Figure 1(d) shows the evaporation of the residue of viscosity at 60^{o}C. With the increase of the content of bio-oil, the viscosity of the two types of emulsified bio-asphalts was not obviously changed when the content was less than 10% at 60^{o}C, then gradually increased when the content is higher than 10%. Through infrared spectroscopy analysis, the bio-oil and base asphalt take chemical reaction in part of the mixture, the unreacted part blended with the base asphalt.

Figure 1(e) shows the trend of standard viscosity with the change of biomass masut. The standard viscosities of the two emulsified bio-asphalts both increased with the increase of the bio-oil content, which indicated that the mobility of the emulsified bio-asphalt decreased with the increase of the content of bio-oil.

Figure 1(f) shows the storage stability of emulsified bio-asphalt with the variation of biomass masut after 5 days. The storage stability of both the emulsified bio-asphalts became worse with the increase of the content of bio-oil. The results of previous fluorescence microscopy showed that there were irregular substances in the mixture after the bio-oil was incorporated into the base asphalt. It was presumed that the irregularities might affect the emulsification process and make the radius of the asphalt particles too large, resulting in poor storage stability.

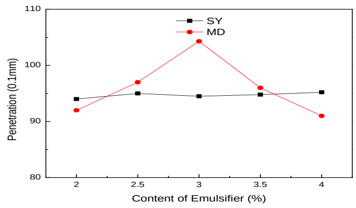
With the increased of the content of biomass masut, two types of emulsified bio-asphalt was in different character. When the content of bio-oil was 15~20%, the emulsified bio-asphalt got the maximum ductility, 60^{o}C viscosity and standard viscosity were moderated, the softening point declined slowly, and the storage stability was better after 5 days. Therefore, the emulsified bio-asphalt played the best performance when the content of biomass masut was 15~20%.

Effect of Different Content of Emulsifier on Performance of Emulsified Bio-asphalt

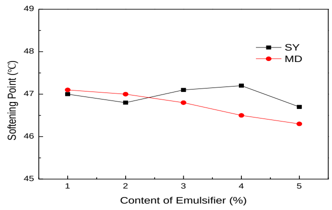
Emulsifier is an essential material for preparation of emulsified bio-asphalt. It is obvious that the effect of emulsified bio-asphalt is greatly influenced by the content of emulsifier. Emulsifier of MD-type and SY-type were used to investigate the effect of different content of emulsifier on preparation of emulsified bio-asphalt in this study. Adding the biomass masut with the content of 15~20%. The performance are shown in table 2 and figure 2.

Table 2. The Impact of Different Content of Emulsifier on Emulsified Bio-asphalt.

Project	Unit	emulsifier				
		2.0%	2.5%	3.0%	3.5%	4.0%
SY-type sieve residue	%	0.07	0.06	0.06	0.05	0.05
MD-type sieve residue	%	0.02	0.02	0.01	0.01	0.01
Breaking speed		Slow crack				

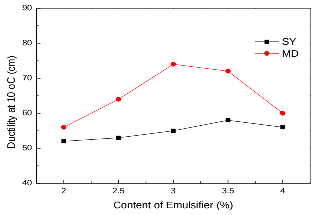


(a) Relationship between emulsifier content and penetration

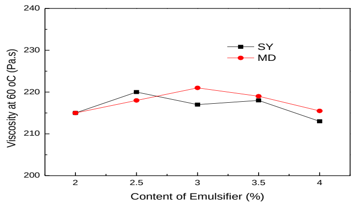


(b)

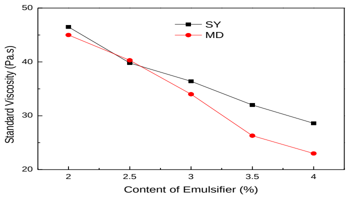
(b) Relationship between emulsifier content and softening point



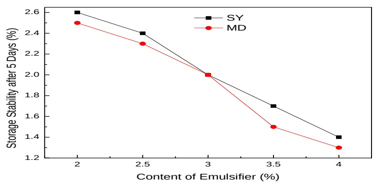
(c) Relationship between emulsifier content and ductility at 10 °C



(d) Relationship between emulsifier content and viscosity at 60 °C



(e) Relationship between emulsifier content and standard viscosity



(f) Relationship between emulsifier content and storage stability after 5 days

Figure 2. The Effect of Content of Emulsifier on Performance of Emulsified Bio-asphalt.

It can be illustrated from Table 2 that the residue of the emulsified bio-asphalt on sieve was less than 0.1%, and decreased with the increase of the emulsifier content. The residue of the emulsified bio-asphalt on sieve of MD-type emulsifier was less than that of SY-type. It was found from the experiment that the charge of emulsified asphalt was cationic and the breaking speed was slow.

It can be seen from Figure 2(a) that with the increase of the content of emulsifier, penetration of SY-type emulsified bio-asphalt was unchanged, indicating that the SY-type emulsifier do not work with the evaporation residue of bio-asphalt; With the increase of the content of emulsifier, the penetration of MD-type emulsified bio-asphalt decreased after first increased. It indicated that MD-type emulsifier promoted the fusion of the asphalt particles slightly. With the increase of the content of emulsifier, the unfavorable factors in the emulsifier affected the fusion of the asphalt particles, leading to a penetration decrease after the initial increase.

Figure 2(b) shows the relationship between the emulsifier content and the softening point. With the increase of the content of emulsifier, softening point of SY-type emulsified bio-asphalt shows a fluctuation trend. The softening point of all the samples were between 46~47^{o}C, which indicated that the two emulsifiers have limited effect on the performance of the residue of emulsified bio-asphalt in high-temperature.

Figure 2(c) shows the regular of ductility with the variation of the emulsifier content at 10^{o}C. The ductility of SY-type emulsified bio-asphalt gradually increases with the increase of the content of emulsifier at 10^{o}C. For MD-type emulsified bio-asphalt, with the increase of the content of emulsifier, the ductility decrease after initial increase at 10^{o}C. The principle was similar to the penetration.

Figure 2(d) shows the evaporation residue of viscosity changes at 60^{o}C. The viscosity of the two emulsified bio-asphalts changed slightly with the increase of the content of emulsifier at 60 ^{o}C, and the curves were wavy. The effect of the SY-type emulsifier on the viscosity of emulsified bio-asphalt evaporation residue had no obvious tend. When the content of emulsifier was higher than 2.5%, the viscosity decreased.

Figure 2(e) shows the trend of standard viscosity with the change of the emulsifier content. The standard viscosity decreased with the increase of emulsifier content, indicating that the mobility of emulsified bio-asphalt increased with the increase of content of emulsifier.

Figure 2(f) shows the storage stability of bio-asphalt emulsion and the variation of emulsifier after 5 days. The figure shows the storage stability increased after 5 days with the increase of the content of emulsifier. Mainly because that the emulsifier in the asphalt particle surface adsorption increased, reduced the surface tension, so improved the storage stability of emulsified bio-asphalt.

With an increase in the content of SY-type emulsifier, the residual amount on the sieve gradually decreased, the penetration and softening point of the evaporation residue remained unchanged, the 60 ^{o}C viscosity had no obvious rule, the standard viscosity decreased after the initial increase, the storage stability after 5 days was improved, and the ductility at 10 ^{o}C decreased after the initial increase. Thus, when the SY-type emulsifier is used, the emulsifier content of 3.5% played the best performance. The residue on the sieve of the MD-type emulsified bio-asphalt decreased, and the penetration and ductility of the evaporation residue decreased after firstly increased at 10 ^{o}C, the storage stability after 5 days was improved, the softening point was slightly decreased, standard viscosity and viscosity at 60 ^{o}C was almost constant. Thus, when the MD-type emulsifier is used, the emulsifier content of 3.0% played the best performance.

4 CONCLUSIONS

This study investigated the influence factors of the emulsified bio-asphalt, including the biomass masut and emulsifier. According to the experiment results, the conclusions can be drawn as:

With an increase in the content of biomass masut, the properties of emulsified bio-asphalt evaporation residue are listed as follows: For SY-type emulsified bio-asphalt, penetration, storage stability, and viscosity gradually increased, while the softening point decreased, and the ductility decreased after initial increase. For MD-type emulsified bio-asphalt, penetration, ductility, softening point were smaller than that of the SY-type. When the content of biomass masut is 15 ~ 20%, the performance plays the best.

When the biomass masut content is 15~ 20%, with the increase content of emulsifier, the properties of emulsified bio-asphalt evaporation residue are listed as follows: With the gradual increase of the content of SY-type emulsifier, the penetration gradually increased, storage stability increased, softening point, viscosity at 60 ^{o}C and standard viscosity were almost unchanged, while the ductility decreased after first increased at 10 ^{o}C. In summary, for the SY-type emulsifier, the performance plays best when the emulsifier content is 3.5%. With the gradual increase of the content of MD-type emulsifier, the penetration and ductility of the evaporation residue firstly increased and then decreased at 10 ^{o}C, and the storage stability improved, softening point slightly decreased, viscosity at 60 ^{o}C and standard viscosity kept unchanged. For the MD-type emulsifier, the performance plays best when the emulsifier content is 3.0%.

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