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Influence of Different Factors of Crumb Rubber on the Properties of Crumb Rubber Modified Asphalt

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Over the years, the waste tires have become a serious environment problem and using the tire rubber in asphaltic concrete mixtures as additives is an effective way to dispose them, The former researches had found that the application of crumb rubber in asphalt binder can improve the binder properties. This research intends to investigate the effect factors of crumb rubber modifier binder in the laboratory. For this study, the crumb rubber modifier binder was produced by the different blending temperatures (160, 180, 200 and 220 ºC), different crumb rubber mesh (40, 60, 80, 100) and different crumb rubber contents (15, 20, 25 and 30 % by weight of asphalt binder). Results observed from this study indicates: (1) the blending temperatures, crumb rubber mesh and crumb rubber contents have great influence on the binder properties; (2) the effect factors exist their optimal ranges, which are thought to be due to the effect factors have different influence on the binder absorption. (3) the optimal ranges about blending temperatures, crumb rubber mesh and crumb rubber contents in this study are 180 ºC, 60 mesh and 25 % by weight, respectively.

Key Words: Crumb rubber modifier binder, Crumb rubber, Asphalt performance, Waste tires, Reuse.

INTRODUCTION

With the rapid development of economic in China, the quantities of autos increase shapely, which produced millions of tons of waste tires into landfill and stockpiles. According to statistics, more than 80 million huge scrap-tires were produced in 2002 and the amounts were up to 112 million in 2004 and 140 million in 2006 with a year by year growing rate[1,2]. Because these waste tires can withstand deteriorate from chemical, mildew and rot, the tire stockpiles and landfills are becoming unacceptable to the local community, for the fire and sanitation concerns[3]. China will face environmental threat related to the disposal massive waste tires in the future.

There are many ways to dispose waste tires at present in the world and the innovative way is using the tire rubber in asphaltic concrete mixture as additives, previous experiences showed that the using of crumb rubber had been proven to be cost-effective, environmentally sound and improved some engineering properties of asphalt mixture[3].

The recycling of crumb rubber adding to asphalt paving material has been an area of interest since 1940s when the US Rubber Reclaiming Company began marketing a recycled rubber product, as a dry particle additive to asphalt paving mixture[4]. Some state departments of transportation have developed the related researches to use rubberized asphalt concrete materials. The respective studies proposal the crumb rubber can be incorporate by a wet process and dry process. The main differences between the two processes consists in rubber particle size, rubber content, rubber function and incorporation facility, the results also show that a large range of crumb rubber can be successfully reclaimed and recycled into improving the properties of the asphalt mixture[5,6].

A great deal of studies have shown that there are many factors affecting the modified effects on asphalt mixture, including the rubber content, particle size and the type of crumb rubber[7-11]. Xiao *et al.*[12] found that with the rubber size increasing, the resilient modulus values would be reduce, which would extend the fatigue life of the modified mixtures. The phase angle and complex modulus were affected by both the surface area and average particle size of crumb rubber. However, the average size is the predominating factor[13], some studies have focused on the interaction time and temperature affecting the modified effects, Jeong *et al.*[11] and Ying *et al.*[14], evaluated the characteristics of crumb rubber modifier (CRM) binders with variable interaction time and variable interaction temperatures. The results indicated that the interaction time and interaction temperatures of crumb rubber modifier binders had significant effects on the binder properties.

The objective of this study is to evaluate the factors (interaction temperatures, mesh sizes, rubber contents) influencing laboratory performance of the crumb rubber modifier. These were accomplished through evaluating engineering properties such as softening point, penetration degree, ductility and elastic recovery.

EXPERIMENTAL

In this study the selected asphalt binder was AH-90, which obtained from a commercial petroleum company, Table-1 shows the physical properties of the base binder. The measure methods for it follow the standard test methods of Bitumen and Bituminous Mixtures for Highway Engineering (JTJ 052-2006).

TABLE-1
PHYSICAL PROPERTIES OF ASPHALT BINDER

Property	Value
Specific gravity (g/cm^3)	1.12
Moisture content (%	0.63
Metal (content %)	0
Fiber content (%)	0.05
Carbon black content (%)	36.1
Ash content (%)	4.1
Nature rubber content (%)	64

The crumb rubber was produced by the Chengdou Xinzhu Road & Bridge machinery Co. Ltd. Because the sizes of the crumb rubber and the production process obviously affect the performance of crumb rubber modifier asphalt, in this study four sizes (40, 60, 80 and 100 mesh) of the crumb rubber were selected, which were obtained by mechanical shredding at ambient temperature. The crumb rubber was cleaned, dried and uniformity, the properties of crumb rubber were tested and showed in Table-2.

TABLE-2
PROPERTIES OF CRUMB RUBBER

Test items (temp.)	Unit	Value	Specification
Penetration (25 ºC)	0.1 mm	83.6	T0604
Ductility (15 ºC)	cm	> 100	T0605
Ductility (10 ºC)	cm	82.35	T065
Softening point (ºC)	ºC	46.75	T0606
RTFO binder			
Mass loss (%)	%	0.260	T0609
Residual penetration ratio (%)	%	68.11	T0604
Ductility at 10 ºC	Cm	25.3	T0605

Experimental design and testing procedures: The experimental design for the study is shown in Fig. 1 and single factor analysis methods were used. During the experiment, keeps one factor changing and the other factors constant, this method can find out the most significant factor and ensure the testing unbiased.

In this analysis, softening point, penetration, low temperature ductility, elasticity recovery were selected as the performance indexes, which can reflect the high and low temperature property, temperature susceptibility and the antifatigue performance. The experimental methods follow the standard test methods of Bitumen and Bituminous Mixtures for Highway Engineering (JTJ052-2006).

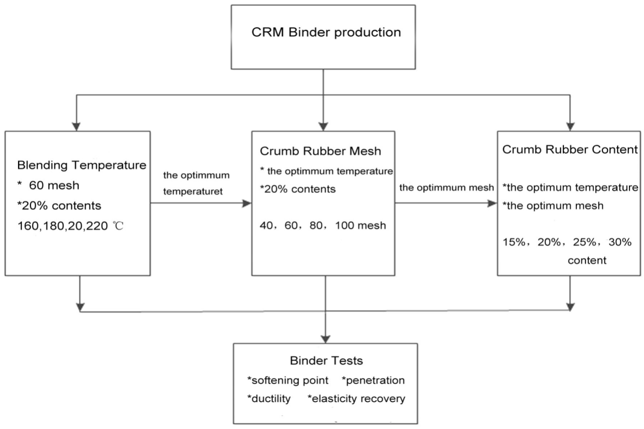

Fig. 1. Flow chart of experimental design procedures for the crumb rubber modifier binder test

The crumb rubber modifier was produced though wet-process, the processing parameters included different sizes, contents and blending temperatures of the crumb rubber. The sizes, contents and temperatures were selected because of the similar researches which have been completed in the past on crumb rubber. The four contents (15, 20, 25 and 30 %) of crumb rubber were used by the total weight of the asphalt binders; the blending temperatures of crumb rubber chosed to be 160, 180, 200 and 220 ºC, the sizes of crumb rubber were 40, 60, 80 and 100 mesh, respectively. The optimum temperature, mesh and content can be obtained by the experiments. The abbreviation shown in Table-3 will be used in this study to discuss the influence of the factors changes on the crumb rubber modifier.

TABLE-3
NAME DESIGNED FOR CRUMB RUBBER ADDITIVE

CRM name	Temp. (ºC)	Content (%)	Mesh	Optimum point
A	160, 180, 200, 220	20	60	180 ºC
B	180	20	40, 60, 80, 100	80 mesh
C	180	15, 20, 25, 30	80	20 % content

RESULTS AND DISCUSSION

Effects of temperature changes on crumb rubber modifier: Performance analysis of crumb rubber modified prepared through wet process was conducted and the results were shown in Figs. 2 and 3.

As shown in Figs. 2 and 3, the softening point, penetration, ductility and elastic recovery are affected obviously by the blending temperatures. The important point to note is that, below 180 ºC, the softening point, penetration, ductility and elastic recovery increase as blending temperature increasing. However, once the blending temperature increases over 180 ºC, the penetration and softening point show a declined tendency, meanwhile, the softening point and elastic recovery still increases but the rate becomes slow. This phenomenon can be explained by the modification mechanism, when the blending temperatures are low, the crumb rubber is harder to blend with asphalt binder, until then an obvious rise in temperature

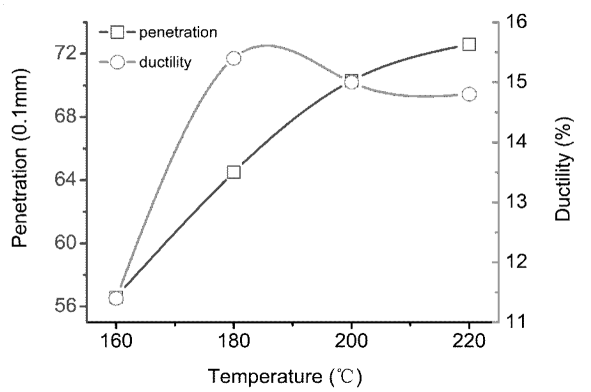

Fig. 2. Effects of temperature changes on the penetration and ductility

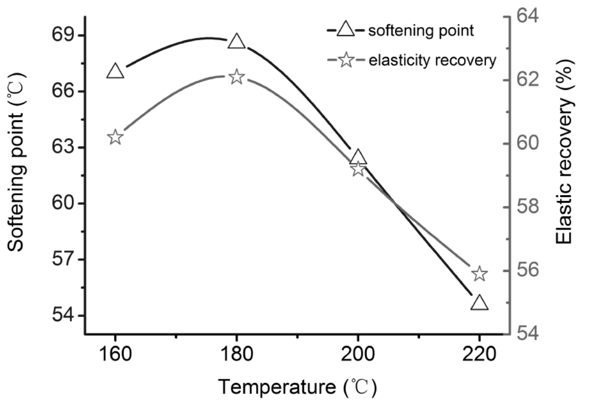

Fig. 3. Effects of temperature changes on the softening point and elastic recovery

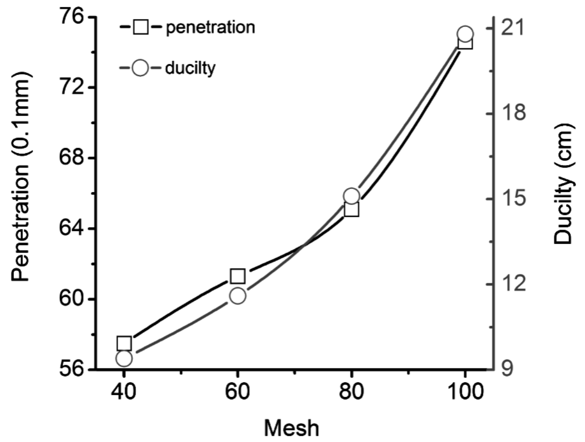

Fig. 4. Effects of mesh changes on the penetration and ductility

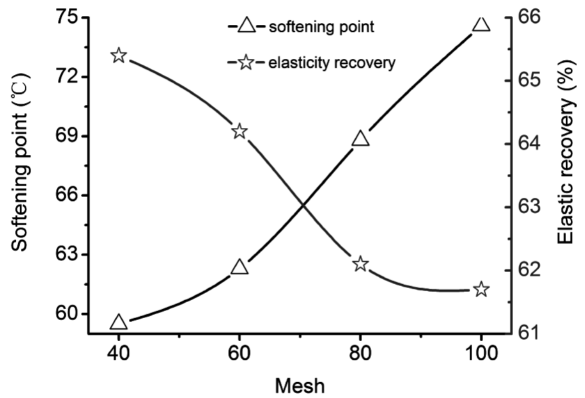

Fig. 5. Effects of mesh changes on the softening point and elastic recovery

(< 180 ºC), the blending reaction becomes acceleration, the crumb rubber would absorbed the light constituents of the asphalt binder, so the engineering properties of crumb rubber modifier have been affected and the softening point, penetration, ductility increases. But when the temperature exceeds 180 ºC, the decrease of penetration and ductility could be related to the evaporation of the light constituents which are absorbed by crumb rubber, the asphalt binder becomes hard-brittle materials.

It can be concluded that the optimum blending temperature through wet process could improve the properties of crumb rubber modifier and the optimum blending temperature in this study was 180 ºC.

Effects of crumb rubber mesh size changes on crumb rubber modifier: The test results for engineering properties of crumb rubber modifier at four crumb rubber mesh sizes of 40, 60, 80 and 100 are illustrated in Figs. 4 and 5. It can be observed that the crumb rubber size had an obvious influence on the engineering properties of crumb rubber modifier binders. It is noticed that, with the crumb rubber mesh increasing, the elastic recovery decrease, while the softening point, penetration degree and ductility increase. The reason could be elaborated as following, generally, when the crumb rubber is smaller in size, the more specific surface areas it have, which makes crumb rubber equally distribute into the asphalt binder. This will allow the blending reaction to proceed to completion. Therefore, the softening point, penetration degree and ductility increase following the crumb rubber mesh increasing. But when the crumb rubber size grows significantly in terms of 40 to 100, the performance of elastic recovery decreases steadily, it is thought to be that the elastic of crumb rubber had begun to decay after it had absorbed the light constituents of the asphalt binder. In addition, the elastic recovery test on crumb rubber modifier binder is conducted at a temperature of 25 ºC using the ductility instrument, it represents the capacity of crumb rubber modifier to return the previous shape after tension. In this study, following the crumb rubber mesh increasing, the tensile capacity increases farther than the resilience capacity. As a result, the elastic recovery of crumb rubber modifier decreases.

Effects of crumb rubber content on crumb rubber modifier: The influence of crumb rubber content on the engineering properties of crumb rubber modifier is shown in Figs. 6 and 7. From which it can be concluded that it exists the optimal content (25 %) of crumb rubber. When the crumb rubber content is below 25 %, the softening point, ductility and elastic recovery increase with the content increasing, it indicates that in an appropriate range (< 25 %), there is more rubber particle in the asphalt with more crumb rubber content, so the light constituents are been absorbed easily and the asphalt could form reticular formation, make the crumb rubber modifier become stability.

However, It is also noticed that the penetration decreases as the crumb rubber content increasing, this can be explained as follows, the crumb rubber absorbed so much light constituents, then, the residual asphalt phase of the crumb rubber modifier

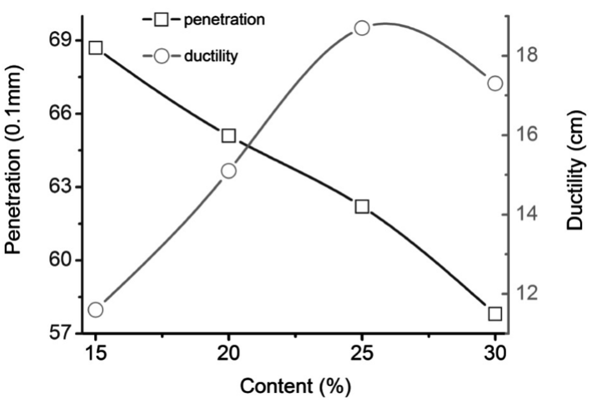

Fig. 6. Effects of content changes on the penetration and ductility

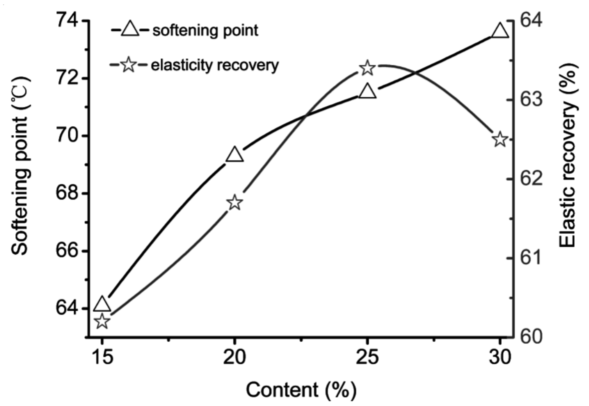

Fig. 7. Effects of content changes on the softening point and elastic recovery

binders has a rigid, also the rubber particle is a rigidity itself, the penetration test on crumb rubber modifier binder is conducted using bitumen-determination of penetration (100 g, 5 s, 25 ºC) in the laboratory, so the rigidity of crumb rubber modifier would affect the pin stuck into asphalt binder.

When the crumb rubber contents exceeds 25 %, the relationship between ductility, elastic recovery and crumb rubber content is not the same as before (Fig. 6). With the increase of content, the ductility and elastic recovery decrease apparently. It is believed this decrease is the result of the rubber particle pushing, due to the crumb rubber content increasing too much.

Conclusion

Laboratory experiments were designed to study the engineering properties of binders on different reaction conditions. Crumb rubber modifier binders were produced in the laboratory at four blending temperatures, with four crumb rubber mesh sizes and four crumb rubber contents, respectively. A series of softening point, penetration, ductility, elasticity recovery were conducted, the following conclusions can be drawn from this study. In general, the blending temperature has a great influence on the properties of the crumb rubber modifier modified binder, the higher blending temperature seems to lead to the increase of the penetration and ductility; the softening point and elasticity recovery exist an optimal temperature of 180 ºC. It shows that the crumb rubber mesh sizes has a statistically significant influence on the crumb rubber modifier binder in this study, the softening point, penetration and ductility increase as the rubber mesh increasing, while the elasticity recovery decreases as the rubber mesh increasing. It indicates that crumb rubber modifier blend with small size of crumb rubber would reaction faster, considering the elasticity recovery; the optimal crumb rubber mesh size is 60. With the crumb rubber content increasing, the penetration of crumb rubber modifier binders is decreasing and the softening point increases following the content rising; while the ductility and elasticity recovery exist an optimal content which was 25 %. The reaction of crumb rubber with asphalt is very complicated, the influence of different rubber and asphalt sources on the modification effect have a great difference, so analyzing and evaluating the influence factors and degrees of variant sources is possibly necessary.

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