Study on the fusion degree of old and new asphalt based on rod-like thin layer chromatography

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Abstract. In order to quantify the fusion behavior of new and old asphalt during the hot recycling process, and to detect the degree of fusion of blended asphalt in different reclaimed asphalt pavement, this paper designs an experimental method to measure the fusion degree of new and old asphalt during the hot recycling process. This method uses magnetite aggregate instead of new aggregate to achieve the separation of new and old materials in the hot recycled asphalt mixture, and uses the "toluene extraction" method to separate the aggregate and asphalt in the hot reclaimed asphalt pavement. The rod-like thin layer chromatography is used to analyze the component changes of asphalt during the hot recycling process, and a formula for calculating the fusion degree of new and old asphalt is proposed. Reclaimed asphalt mixture from different sources are tested and the results show that it can accurately and effectively measure the fusion degree of new and old asphalt during the hot recycling process. The degree of fusion of blended asphalt in different milling materials varies greatly, mainly due to the complexity of milling processes and sources, but their fusion degree is less than 50%.

Keywords: Asphalt fusion behavior; rod-like chromatography analyzer; magnetite aggregate; fusion degree of new and old asphalt

1 Introduction

The majority of roads around the world are made of asphalt mixtures. However, due to the rapid expansion of the traffic volume and the road surfaces reaching the end of their service life, a large number of road surface diseases have appeared, seriously affecting driving safety and ride comfort [1-3]. Therefore, in the next few years, the focus of the world's highway industry development will gradually shift from road construction to road maintenance [4-6]. In daily asphalt road maintenance work, a large amount of asphalt recycling materials will be produced. If these asphalt recycling materials are not utilized, they will not only cause a lot of waste, but their accumulation will also cause pollution to the surrounding ecological environment [7]. There has been a certain scale of utilization for recycled asphalt pavement (RAP). However, the utilization rate of RAP is not high, and it is strenuousto exactly evaluate the state of asphalt in RAP

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materials, as well as to quantitatively evaluate the degree of asphalt fusion in hot recycled asphalt mixtures [8-9]. These are factors that affect the early occurrence of diseases in hot recycled asphalt mixtures. Scholars have conducted extensive research on the fusion of new and old asphalt technologies. Some research reports have shown that the asphalt in RAP will form a new binder with new asphalt, which will affect the performance of asphalt mixtures [10]. Furthermore, certain academics have examined the fusion interface of new and old asphalt mixtures [11], and found that the level of blending between fresh and existing asphalt mixtures is closely related to the recycling process. Furthermore, regarding the fusion ability of asphalt recycling agents and asphalt, some scholars have deeply analyzed the degree of fusion between recycling agents and asphalt by modifying the matrix asphalt marker [12].

2 Test methods

2.1 Separation of new and old materials

In this research, magnetite aggregates were employed as fresh aggregates, and the separation of new and old materials in the recycled asphalt mixture was achieved by relying on the characteristic that magnetite aggregates can be attracted by a magnet. The steps for separating the new and old materials should involve adding magnetite aggregates, new asphalt, and RAP according to the designed gradation ratio, where the 4.75-9.5 mm size range of the new aggregates is the magnetite aggregate. The schematic diagram of separated magnetite is shown in Figure 1.

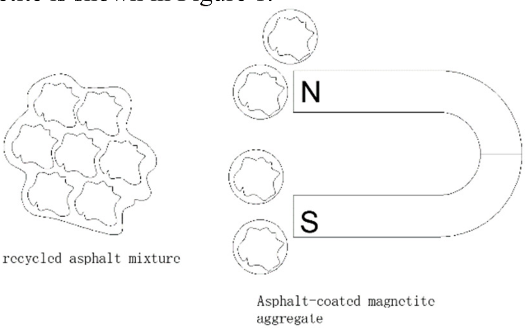


Fig. 1. Schematic diagram of separated magnetite

2.2 Separation of asphalt and aggregate

The “oil-stone separation” step should be carried out on the separated magnetite aggregate with attached asphalt to separate it into magnetite aggregate and asphalt, easing the burden of detecting the asphalt. In this review, the “toluene extraction” method was used to separate the aggregate and asphalt, and the specific steps are described below:

Step 1: We take an appropriate amount of separated magnetic ore concentrate and transfer it into a small flask. We weigh it as M and soak it in an appropriate volume of toluene. We have to make sure that the magnetic ore concentrate is completely submerged in toluene. We seal it with sealing film and let it stand for five hours.

Step 2: Once all of the asphalt in the magnetic ore concentrate has dissolved in toluene and the fine particles have settled to the bottom of the small beaker, we proceed to gently pour the asphalt-toluene solution into a volumetric flask and measure the volume as V. It is crucial to avoid any fine particles from being included in the solution poured out.

Step 3: The beaker with the leftover fine particles is subjected to a forced ventilation drying oven at a temperature of 105 °C ± 5 °C. After cooling, we weigh the weight as M_0.

$$\mathrm{V} = \frac{100}{3} \times (M - Mo) - V \tag{1}$$

2.3 Rod-like chromatography analyzer

We drop the extracted solution obtained from the above steps onto the chromatography stick, use a developing agent to develop it, ignite the chromatography stick with a hydrogen flame, and perform quantitative analysis based on the different chromatographic peaks of each component using the ratio of correction factors. The test flow chart is shown in Figure 2.

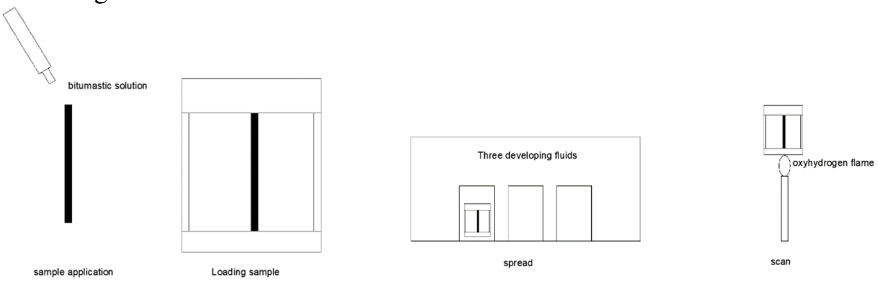


Fig. 2. Test flow chart

3 Experiment Program

3.1 The preparation of new and old materials

We separate the asphalt and aggregate from RAP using an automatic extractor, recover the old asphalt using a rotary evaporator, and test its relevant indicators. The relevant indicators of new and old asphalt are documented in Table 1.

Table 1. Key technical indicators of new and old asphalt.

Project	New asphalt	Old asphalt	Technical indicators
Penetration Index (25 °C), 0.1 mm	69	26	60-80

Ductility (10 °C), cm	34	4	25
softening point, °C	49.0	64.0	>46
RAP asphalt content, %	-	5.5	-

As indicated in Table 1, the degraded asphalt in the RAP has undergone aging. The reason for this is that under the influence of environmental factors and loading conditions, the light components of the asphalt evaporated or transformed, causing it to become harder and age. According to the asphalt penetration grade blending formula, the final amount of new asphalt is determined to be 5%, which can meet the specification requirements.

3.2 The gradation of asphalt mixture

The selection of fresh asphalt and virgin aggregates is based on raw materials that meet relevant technical specifications, with pass rates shown in Table 2. For the 4.75-16 mm size range, magnetite aggregate is used

Table 2. Aggregate and Gradation Passing Rates.

Project	Aggregate	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Magnetite Aggregate 10-15 mm	15	100.	74.7	4.2	0.4	0.4	0.4	0.4	0.4	0.4	0.2
Magnetite Aggregate 5-10 mm	5	100	100.0	91.8	4.0	0.3	0.3	0.3	0.3	0.3	0.2
Recycled Asphalt Pavement	79	100.	98.8	97.2	64.9	40.6	27.0	19.1	12.3	8.8	5.2
Mineral Powder	1	100	100	100	100	100	100	100	100	96	80.8
AC-13 Specification Lower Limit Gradation	-	100	90.0	68.0	38.0	24.0	15.0	10.0	7.0	5.0	4.0
AC-13 Specification Upper Limit Gradation	-	100	100.0	85.0	68.0	50.0	38.0	28.0	20.0	15.0	8.0
Gradation Median Value	-	100	95.0	76.5	53.0	37.0	26.5	19.0	13.5	10.0	6.0
Synthetic Gradation	-	100	95.3	83.0	52.5	33.1	22.4	16.2	10.8	8.0	5.0

After gradation design, the optimal gradation is determined as shown in Table 2, and the optimal asphalt content is obtained as 4.9%.

3.3 The separation of new and old asphalt

The materials for each size range and new asphalt are mixed according to the specification requirements. The uniformly mixed asphalt mixture is then spread on the pan, and after cooling, a magnetite aggregate of 5-10 mm is extracted using a magnet, resulting in magnetite aggregate coated with blended asphalt.

4 Test Conclusions and Analysis

4.1 The relationship between asphalt index and its components.

The most direct method to evaluate the performance of asphalt is to measure its macroscopic indicators. The microscopic components of asphalt can accurately reflect the microscopic structure of asphalt, but they are not easy to quantify. Scholars made new progress in the research direction of the influence of asphalt component composition on asphalt physical properties [13]. Through the use of multivariate regression analysis, the researchers investigated the connection between the physical indicators of diverse asphalt varieties and their aging residues, as well as the asphalt components and molecular weight. They established a regression correlation between the macroscopic and microscopic properties of asphalt through experimentation. One such regression formula pertains to the logarithm of asphalt penetration and its components.

$$lgP=7.515-0.116At+0.060S-0.123R \quad (2)$$

the equation presented above employs the following parameters: P, indicating the penetration value of asphalt in 0.1mm; At, which denotes the asphalt content measured in percentage; S, representing the saturation content also measured in percentage; and R, which represents the resin content measured in percentage.

4.2 Method for calculating the fusion of new and old asphalt.

According to JTG/T 5521-2019, when determining the amount of new asphalt, the new asphalt grade should be formulated based on the blending rule of new and old asphalt, as shown in Formula 2.

$$lgP_{mix}=(1-\alpha)lgP_{old}+\alpha lgP_{new} \quad (3)$$

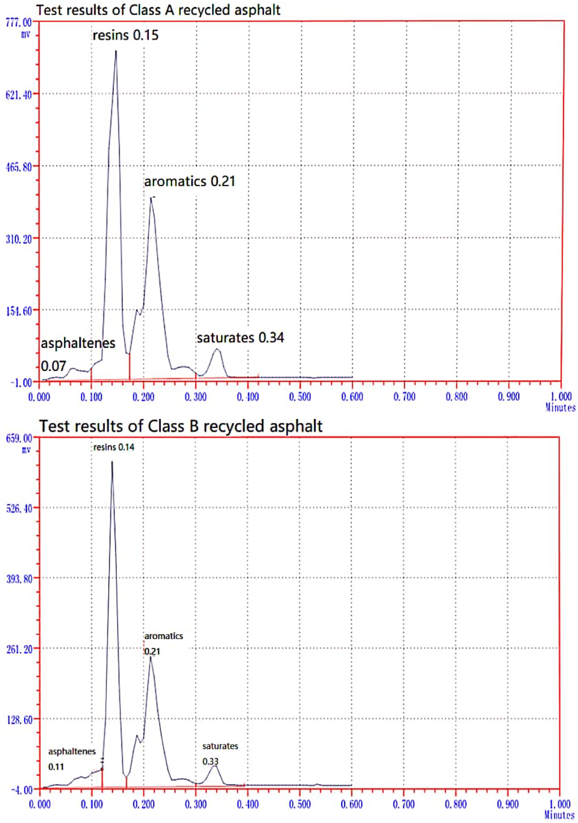
where P_{mix} represents the penetration value of the blended asphalt, 0.1 mm, after mixing new and old asphalt; P_{old} represents the penetration value of the old asphalt before blending, 0.1 mm; P_{new} represents the penetration value of the new asphalt before blending, 0.1 mm; α represents the proportion of new asphalt. This formula is proposed on the premise of complete blending of new and old asphalt, which can achieve the penetration level after sufficient blending of new asphalt and old asphalt in RAP. However, extensive research has shown that it is impossible for all old asphalt to play a role in the amalgamation of new and old asphalt. Therefore, assuming the degree of old asphalt participation in the blending process as β during the hot recycling process, the degree of blending β can be calculated by transforming the blending rule of new and old asphalt. The formula for calculating the degree of blending of fresh and aged asphalt is shown in the formula.

$$\beta = \frac{\alpha \lg P_{new} - \alpha \lg P_{mix}}{(1-\alpha)\lg P_{mix} - (1-\alpha)\lg P_{old}} \tag{4}$$

where β represents adhesion strength between virgin and reclaimed asphalt, expressed as a percentage; α represents the proportion of new asphalt to the total amount of asphalt, expressed as a percentage; $\lg P_{new}$ is the logarithmic penetration value of the new asphalt; $\lg P_{old}$ is the logarithmic penetration value of the old asphalt; $\lg P_{mix}$ is the logarithmic penetration value of the blended asphalt attached to the surface of the new aggregate.

4.3 Determination of Asphalt Components

We calculate the mass of magnetite aggregate needed for measuring the asphalt components, weigh the magnetite aggregate coated with blended asphalt using the quartering method, and record the mass. We prepare a 30 mg/ml toluene solution of asphalt. Using a thin-layer chromatography instrument, we establish the composition ratio of the asphalt on the magnetite aggregate according to the operational steps. We repeat the same method to detect the old asphalt on RAP and new asphalt, with the detection results shown in the figure 3 below.



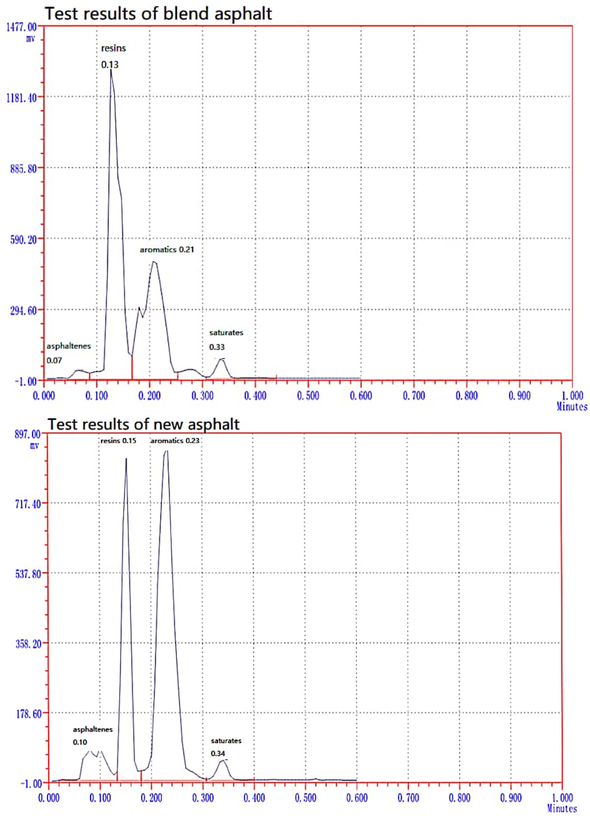


Fig. 3. Chromatographic analysis of new and old asphalt as well as blended asphalt.

4.4 Calculate the degree of blending.

We calculate the logarithm of the penetration index for new asphalt, old asphalt, and blended asphalt according to Formulas 2 and 3. Then, we input the above results into Formula 4 to obtain the degree of blending β. Considering the variability of the actual RAP, the RAP is measured twice, and the results can be found in Table 3.

Table 3. Calculation of asphalt blending degree.

Type of Asphalt		Calculated Index of Asphalt					
		Asphaltenes	Resins	Aromatics	Aaturates	Logarithm of Penetration Index	Degree of Blending of New and Old Asphalt
New asphalt		6.98	18.21	65.44	9.31	5.002	-
Blended asphalt		3.01	32.69	47.31	16.88	4.118	-
Old asphalt	a	2.42	38.91	44.81	13.88	3.278	26.3
	b	6.21	32.51	44.77	16.91	3.855	48.1

Taking into account the experimental observations, it can be seen that the design method can be used to determine the degree of blending between fresh and aged asphalt during the hot recycling process. This method is easy to operate and solves the problem of difficulty in determining the blending status of new and old asphalt in hot asphalt mixes incorporating reclaimed materials. When the proportion of old asphalt participating in the blending of new and old asphalt is less than 50%, the degree of the combination of virgin and recycled bitumen is also less than 50%. The results of the two measurements were 26.3% and 48.1%, respectively. Since RAP was prepared by actual road milling, the degree of blending between mixing fresh and reclaimed asphalt in hot mix asphalt recycling mixtures prepared from different RAPs varies greatly. The degree of blending between new and old asphalt in some hot recycled asphalt mixtures is less than 50%, and even less than 30% in some cases, indicating a poor blending effect. This suggests that most of the old asphalt on RAP did not collaborating in blending of original and recycled asphalt, and most of the old asphalt did not play a role.

5 Conclusion

(1) By using magnetite aggregate as the new aggregate and mixing it with new asphalt and RAP material, the separation of new and old aggregates was achieved by utilizing the characteristic of magnetite that can be attracted by a magnet. The asphalt components were determined by using the method of rod-like thin-layer chromatography, and the “toluene extraction” method was designed to separate the surface asphalt of the hot recycled asphalt mixture

(2) Based on the theoretical knowledge of the relationship between asphalt microstructure and macroscopic properties, and the principle of blending old and new asphalt, a formula for calculating the extent of mixing between old and new asphalt was calculated. This method can accurately measure the fusion degree of old and new asphalt during the hot recycling process.

(3) The measured integration reclaimed and unused asphalt bitumen in hot in-place asphalt recycling mix was less than 50%, and the unevenness of the RAP material resulted in a significant difference in the fusion degree of old and new asphalt.

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