Engineering Application Research of the Wet Processing Produced Buton Rock Modified Asphalt in Anhui Province, China

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Abstract: The Buton rock modified asphalt has the similar high temperature performance with the SBS modified asphalt, but the price is much less than the SBS asphalt. Moreover, it can be highly integrated with asphalt without polymerization, and has been considered as a green road construction materials. Wet processing technique has been chosen to produce the Buton rock modified asphalt, compare with the traditional dry processing technique, natural rock modified asphalt is much more easier to fuse with asphalt, and the performance of the mixture could be much stable. With the application of the wet processing Buton rock modified asphalt in Anhui Province, China, the mix design method and road performance has been tested and researched, and the tests results could meet the requirements of the national specification.

Key words: Buton rock modified asphalt, wet processing technique, asphalt mixture, mix design, road performance test.

1. Introduction

Rock asphalt is a kind of asphalt that formed from petroleum flowing into rock cracks after billions of years with the combined action of heat, pressure, oxidation, catalyst and bacteria. The rock asphalt materials have high quality road service capacity, especially in the performance of high temperature stability, water resistance and durability [1], [2]. Its performance is seemed to be similar as the SBS modified asphalt, but with a very competitive cost which is nearly half of the SBS asphalt. Moreover, the rock asphalt is a kind of nature materials, it has high degree of fusion with asphalt and does not require chemical processing, thus, it could be regarded as a kind of pavement material with the advantages of green-construction, energy-saving, and environmentally friendly.

The rock asphalt researched in this paper is the Buton rock modified asphalt (B.R.A.) with the raw materials form the Buton island of Indonesia. The usage method of the B.R.A. could be divided into “wet process” and “dry process”. The former applies the B.R.A. as the modifier to the basic asphalt, firstly fuse the B.R.A. micro-particles with the basic asphalt to make the B.R.A. modified asphalt, then mixing the modified asphalt with aggregate to form mixture. The latter uses the B.R.A. as admixture, that disperse its particles during the mixing process of the basic asphalt and aggregate, and then mix the three together to form a mixture [3].

Dry process rock asphalt has been used many years in China, because of the restriction of inadequate fusion with the asphalt mixture in the short time, the performance has been adversely affected to some extent. Comparatively, wet process has advantages in easily quality control and stable performance, which is much more suitable for engineering application. Therefore, adopt wet process technique could be an important approach to boost the application of the rock asphalt [4], [5].

To test the performance of the wet process Buton rock asphalt, the test road was constructed in Anhui province, China. The pavement type was AC-13 (expressed as B.R.A.-13 in this paper to indicate the material), designed by the standard of the national road level two. The mix design and road performance has been researched and analyzed in this paper.

2. Mix Design of the Wet Process Rock Asphalt Mixture

2.1. Raw Materials

A test road has been conducted in Anhui province. The coarse and fine aggregates used were both limestone from the local site, which respectively sized (10～15) mm, (5～10) mm, (3～5) mm, (0～3)mm. Performance test results of the aggregates are shown in Table 1. The aggregates were all meet the requirements of the specification [6],[7].

Table 1. Testing Results of Aggregates

Item	Aggregate size (mm)				
	10～15	5～10	3～5	0～3	Mineral powder
Apparent relative density	2.756	2.734	2.724	2.586	2.686
Dry surface relative density	2.732	2.704	2.688	/	/
Gross volume relative density	2.718	2.687	2.667	/	/
Water absorption (%)	0.51	0.65	0.79	/	/
Needle flake content (%)	/	/	/	/	/
Crushing value (%)	/	/	/	/	/
Content ＜0.075mm (%)	0.5	0.4	1.2	6.1	/
Sand equivalent (%)	/	/	/	/	/

The 90# asphalt was used, and the technical requirements and testing results of the 90# asphalt are shown in Table 2. The asphalt was meet the requirements of the specification [6], [7].

Table 2. Technical Requirements and Testing Results of the 90# Asphalt

Item	Unit	Test result	Requirement
Needle penetration (25℃, 5s, 100g)	0.1mm	68	60～80
Softening point (R&B)	℃	47.5	≥46
Ductility (15℃)	cm	>100	≥100
Relative density (25℃)	/	1.010	Actual measurement

Table 3. Test Results of Aggregate Sieving

Aggregate size (mm)	Sieve size (mm)												
	31.5	26.5	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
	Sieve passing rate (%)												
10～15	100.0	100.0	100.0	98.8	94.2	8.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5～10	100.0	100.0	100.0	100.0	99.2	77.1	1.4	0.4	0.4	0.4	0.4	0.4	0.4
3～5	100.0	100.0	100.0	100.0	100.0	100.0	81.9	12.1	2.5	1.3	1.2	1.2	1.2
0～3	100.0	100.0	100.0	100.0	100.0	100.0	98.4	78.4	60.4	38.0	17.1	8.7	6.1
Mineral powder	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	92.8

2.2. Aggregate Gradation Design

According to the national Standard Test Methods, sieving the aggregates by water washing method [6], the sieving results are shown in Table 3. Mixing the aggregates, the gradation results are shown in Table 4, and the gradation curve is shown in Fig. 1.

To guarantee the better performance of high temperature stability and fatigue resistance of the asphalt pavement, reducing the phenomenon of early stage water damage caused by excessive porosity, in the process of mix design in this paper, the void volume (VV) was pre-designed to be 4.5%.

Table 4. B.R.A.-13 Aggregate Proportion and Synthetic Gradation

Aggregate size (mm)	Mix proportion (%)	Sieve size (mm)												
		31.5	26.5	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
		Sieve passing rate (%)												
10～15	24	24.0	24.0	24.0	23.7	22.6	2.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5～10	35	35.0	35.0	35.0	35.0	34.7	27.0	0.5	0.1	0.1	0.1	0.1	0.1	0.1
3～5	5	5.0	5.0	5.0	5.0	5.0	5.0	4.1	0.6	0.1	0.1	0.1	0.1	0.1
0～3	32	32.0	32.0	32.0	32.0	32.0	32.0	31.5	25.1	19.3	12.1	5.5	2.8	2.0
Mineral powder	4	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.7
Synthetic gradation		100.0	100.0	100.0	99.7	98.3	70.0	40.2	29.9	23.7	16.4	9.8	7.1	6.0
Maximum of target gradation		100.0	100.0	100.0	100.0	100.0	85.0	68.0	50.0	38.0	28.0	20.0	15.0	8.0
Minimum of target gradation		100.0	100.0	100.0	100.0	90.0	68.0	38.0	24.0	15.0	10.0	7.0	5.0	4.0

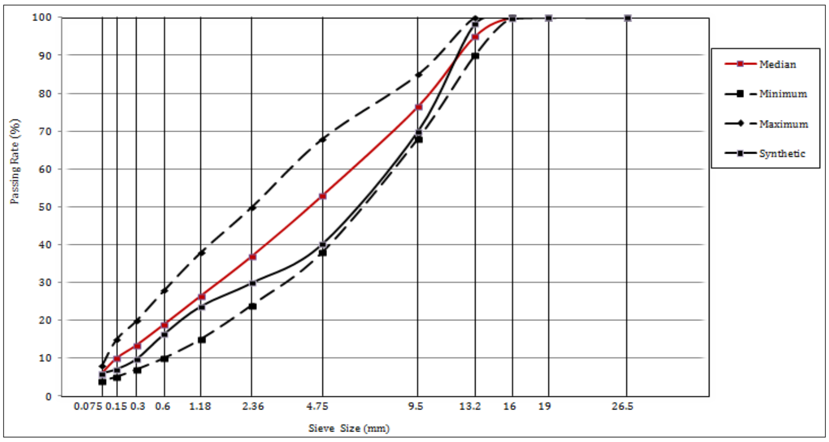


Fig. 1. The synthetic gradation curve.

Table 5. Results of the Marshall Tests

Asphalt aggregate ratio (%)	Maximum theoretical relative density	Gross volume relative density	VV (%)	VMA (%)	VFA (%)	MS (kN)	FL (mm)
4.4	2.570	2.393	6.9	14.4	53.2	9.6	2.6
4.8	2.534	2.397	5.4	14.5	64.0	10.8	2.8
5.2	2.505	2.412	3.7	14.2	74.9	12.6	3.5
5.6	2.478	2.404	3.0	14.4	78.5	11.9	2.7
6.0	2.456	2.404	2.1	14.3	85.0	12.3	2.7

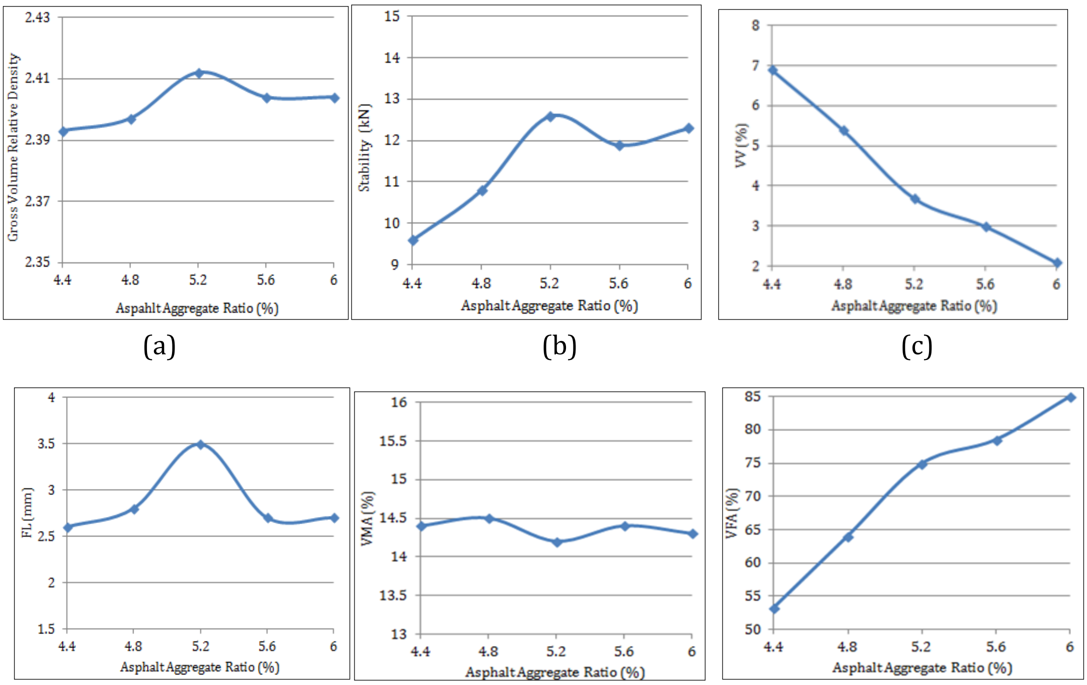
2.3. Determination of the Optimum Asphalt Aggregate Ratio

According to the national Standard Test Methods, compact the Marshall specimen 75 times for each side [6], the target designing void volume was 4.5%, other indicators has all met the technical requirements in the national specification [7].

During the process of the mix design, the heating temperature for asphalt was 150℃～155℃, and for the aggregates was 155℃～160℃. The mixing temperature was 155℃～160℃, and the compaction temperature was 150℃～155℃.

All specimen were individually mixed and compacted. The Marshall test results and technical requirements has been shown in Table 5. The maximum theoretical relative density of the mixture was tested by the actual measurement method.

According to Marshall test and calculation results, respectively draw the relationship curves between gross volume relative density, stability (MS), void volume (VV), flow value (FL), voids in mineral aggregate (VMA), voids filled with asphalt (VFA) and asphalt aggregate ratio. The curves are shown in Fig. 2.



(a) (b) (c)

(d) (e) (f)

Fig. 2 (a)~(f). Relationship curves between gross volume relative density, stability (MS), void volume (VV), flow value (FL), voids in mineral aggregate (VMA), voids filled with asphalt (VFA) and asphalt aggregate ratio.

According to the results in Table 5, Fig. 2, and the calculation method of the asphalt aggregate ratio from the national specification [6], [7], as the target void volume corresponded the asphalt aggregate ratio was *a*3=5.0%, then OAC1=5.2%. According to the relationship curve between the VV and the asphalt aggregate ratio, the relationship curve between the VFA and the asphalt aggregate ratio, it could be seen that OACmin=5.2%, OACmax=5.3%, then OAC2=5.2%. The optimum asphalt aggregate ratio was finally determined as the median of OAC1 and OAC2, and could calculated as 5.2%.

Conduct the Marshall test to the specimen under the optimum asphalt aggregate ratio, all indicators has met the requirements of the standard, the test results are shown in Table 6.

Table 6. Marshall Test Results under the Optimum Asphalt Aggregate Ratio

Asphalt aggregate ratio (%)	Maximum theoretical relative density	Gross volume relative density	VV (%)	VMA (%)	VFA (%)	MS (kN)	FL (mm)
5.2	2.505	2.412	3.7	14.2	74.9	12.6	3.5
Technical requirement			3～6	⩾14.0	65～75	⩾8.0	1.5～4

3. Road Performance Tests of the Wet Process Buton Rock Asphalt Mixture

After paving the test road, the high temperature performance, water stability tests were conducted to assess the road performance of the wet process B.R.A. road. All indicators have met the requirements of the national specification, the test results are shown from Table 7 to Table 9.

3.1. High Temperature Performance

Evaluation high temperature performance by dynamic stability test，the test results are shown in Table 7.

Table 7. Results of the Rutting Test

Type of mixture	Asphalt aggregate ratio (%)	Test results of dynamic stability (times/mm)				Technical requirement (times/mm)
		1	2	3	Average	
Wet process B.R.A.-13	5.2	3299	3158	3500	3319	⩾2800

3.2. Water Stability Performance

Evaluation of water stability by freeze-thaw splitting test and immersion Marshall test, the test results are shown in Table 8 and Table 9.

Table 8. Results of the Freeze-thaw Splitting Test

Type of mixture	Asphalt aggregate ratio (%)	Splitting strength before freezing and thawing (MPa)	Splitting strength after freezing and thawing (MPa)	Residual strength ratio (%)	Technical requirement (%)
Wet process B.R.A.-13	5.2	0.915	0.783	85.6	⩾80

Table 9. Results of the Immersion Marshall Test

Type of mixture	Asphalt aggregate ratio (%)	Stability of specimens immersed in water for 30min (kN)	Stability of specimens immersed in water for 48h (kN)	Residual stability (%)	Technical requirement (%)
Wet process B.R.A.-13	5.2	10.81	9.84	91.0	⩾85

4. Conclusion

(1) According to the mix design, the aggregate gradation was (10～15)mm: (5～10)mm: (3～5)mm: (0～3)mm: Mineral powder = 24:35:5:32:4. The optimum asphalt aggregate ratio was 5.2%.

(2) The test results of dynamic stability, residual strength ratio of freeze-thaw splitting and residual stability of immersed Marshall of the wet process B.R.A. have all met the requirements of the national specification. Besides, the dynamic stability test results was similar to the SBS modified asphalt mixture which was considered to be around 4000 times/mm according to the engineering experience, which was much highly better than the basic asphalt mixture. It indicated that the wet process B.R.A. could improve the high temperature performance of the asphalt pavement and has met the research purpose of this paper.

(3) In order to prevent segregation of the mixture during construction, the grading of raw materials should be strictly controlled when paving. Meanwhile, strengthened compaction was suggested during construction, to ensure the compaction degree of the asphalt pavement layer.

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