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The performance test and evaluation of rock asphalt modified asphalt and mixture

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In order to study rules of property variation of modified asphalt with rock asphalt and its mixture, Binzhou 90# base bitumen and Maoming 70# base bitumen are modified respectively with Xinjiang rock asphalt of 5, 10, 15 and 20%. Property variation of modified asphalt is studied through conventional indexes of grading index penetration system and DSR, BBR as well as quantities of experiments on modified asphalt graded as AC-13 in properties of high temperature, water stability, low-temperature crack resistance and fatigue. The results show that the modifier of rock asphalt is helpful to improve the performance of asphalt at high temperature, but it may also affect the performance at low temperature. The optimum content range of rock asphalt should be controlled in 5 ~ 15%. The improvement in performance of modified asphalt is helpful to the high -temperature performance, water stability and fatigue property of its mixture, but the low-temperature performance may get worse in a small range.

Key words: rock asphalt; modified asphalt; asphalt mixture; test and evaluation

INTRODUCTION

With the rapid development of transportation industry, the road performance of asphalt pavement should meet higher requirements for heavy and canalized traffic. The wide use of modified asphalt in high-grade pavement greatly improves asphalt mixture's road performance. Currently, effective and widely used modifiers are mainly SBS, PE, SBR, etc. However, with the rise in prices of SBS and other modifiers, it is becoming a hotspot in transportation domain to find a modifier of low price and good effect.

Rock asphalt is a stable kind of natural asphalt and Overseas studies have shown that the modifier of rock asphalt will improve mixture's road performance, especially in its high-temperature stability, water stability and fatigue resistance. However, the engineering application of rock asphalt, especially the natural storage in Kalamayiwuerhe, Xinjiang and Qingchuan, Sichuan, etc, is limited for a lack of detailed and clear methods and standards but principle technical requirements by the current specification. The objective of this study is evaluating rules of property variation of modified asphalt with rock asphalt of Kalamayi, Xinjiang and its mixture through experiments, providing reference to our country's rock asphalt's engineering application.

MATERIALS AND METHODS

Materials

Bitumen

Considering effects of different base bitumen to experiments, Binzhou 90# and Maoming 70# base bitumen were used respectively.

Rock asphalt used in this study is Xinjiang Wuerhe rock asphalt.

Aggregate

As for the modified asphalt mixture's tests, if without special explanations, the coarse aggregate was Chengde, Hebei graded basalt material, the fine aggregate was limestone sand and the filler was limestone filler.

Gradation

The use of AC-13 as asphalt mixture's gradation is given by stipulation in the current specification to insure that testing results are stable and reliable.

Material Preparation

Base bitumen and rock asphalt

According to related experiment stipulation, Binzhou 90# and Maoming 70#base bitumen have been tested with conventional indexes and testing results meet requirements, which is listed in Table.1 and those of Wuerherock asphalt are indicated in Table.2

Table 1. Technical index of base bitumen

Pilot projects		Types of base bitumen Binzhou AH-90	Maoming AH-70
Penetration(100g，5s，25°C) 0.1mm		87	67
Ductility(5cm/min，15°C） cm		>150	>100
Softening point(ring and ball method)°C		45.3	48.3
RTFOT（160°C 5h）	Loss of mass %	0.29	0.41
	penetration ratio %	58.6	59.7
	Ductility (25°C) cm	>150	>100
	Ductility (15°C) cm	>150	54

Table 2. Technical index of rock asphalt

Pilot projects	Unit	Test results
Asphalt content	%	99.4
Ash content	%	0.54
Specific gravity	g/cm³	1.06
Flash point	°C	＞230°C
Loss of mass	%	0.632
Moisture content	%	0.1%
Maximum particle size of mineral	mm	4.75

Gradation

To ensure the accuracy of grading, the target gradation of AC-13 is compounded by aggregates of single size sieving from qualified coarse aggregates by standard sifter, blended with fine aggregates.

Modified asphalt and asphalt mixture

Binzhou 90# and maoming 70# base bitumen were preheated to 150°C and rock asphalt was blended in with predetermined proportion of 5, 10, 15 and 20%. Heat and stir them to disperse rock asphalt gradually in base bitumen, then continue at 175°C for 30 min and preserve it in an oven for 1h and then blend it at 175°C for 15 min for later use of pouring an asphalt model. In addition, the method of high-speed shearing can also be used to prepare samples.

The match ratio design of asphalt mixture was determined by Marshall mix design method according to the current specification. In the experiment, the heating temperature of the asphalt mixture was 185°C, the mixing temperature was 175°C, and the compaction temperature was 160°C, according to the viscosity curve of the rock asphalt.The match ratio design of asphalt mixture was determined by Marshall mix design method according to the current specification. In the experiment, asphalt mixture's testing temperature of aggregate, mixing and compaction were at 185,175 and 160°C according to the modified viscosity temperature curve. According to the preparation method, the modified asphalt was prepared in advance, and then the rock bitumen modified asphalt was added into the mineralizer for 90s to obtain the rock asphalt modified mixture. Finally, the mineral powder was added and then mixed for 90s.

According to the tests, the results of the match ratio design of Binzhou 90# base bitumen were shown in fig.3 to fig.8 and its OAC was 4.9%. Note that the optimum amount of asphalt with different content of rock asphalt may change as a result of blending modifier and changes in viscosity and other indexes of itself. In this paper, the same optimum amount of asphalt is taken with different content of modifier, which emphasizes the comparison of how different quality of asphalt may affect the properties of mixtures.

Tests of bitumen

Penetration, ductility and softening point tests

Penetration reflects asphalt's deformation capacity under loading. Ductility reflects asphalt's ability to resist cracks. As for the softening point, it can reflect asphalt's high-temperature performance and is closely connected with asphalt mixture's rut resistance. This study modifies Binzhou 90# or Maoming 70# base bitumen with Xinjiang rock asphalt of 5, 10, 15 and 20% respectively for penetration test at 5, 15, 25 °C, for ductility, softening point and toughness test at 5, 15°C before and after aging according to the test procedure.

Tests of asphalt mixture

Marshall tests, rutting tests and water stability tests

The Marshall Test method is used for the HMA proportion design, according to the current technical specification. This study modified Binzhou 90# base bitumen and Maoming 70# base bitumen with rock asphalt of 5, 10, 15 and 20% graded as AC-13. The test specimen adopts the same asphalt-aggregate ration according to relevant test procedures. The number of a single group of specimen is not less than 4 to test asphalt mixture's stability and flow value. The residual stability of immersion Marshall test and freeze thawing split test's residual strength are two main indexes to evaluate asphalt mixture's resistance to water damage.

Tests of low-temperature performance

According to current specification, low-temperature bending test is used to evaluate asphalt mixture's low-temperature crack resistance. Binzhou 90# base bitumen and Maoming 70# base bitumen were modified with rock asphalt of 5, 10, 15 and 20% respectively by wheel roller. The track board was compacted by wheel grinding and was cut into beams of 250×30×25mm at -10°C and the loading rate was 50mm/min. Asphalt mixture's low-temperature crack resistance is evaluated by failure strain at low temperature.

ANALYSIS

Asphalt

Ductility test results

Penetration test results As is shown in Fig.1 and Fig.2, modified Binzhou 90# and Maoming 70# base bitumen show similar rules:

① At the same temperature, modified asphalt's penetration is obviously lower than that of base bitumen and the penetration reduces with the increase of the proportion of rock asphalt. This means that modified asphalt is stiffer and stronger in deformation resistance.

② Equivalent softening point T800 is significantly lower after modification. With the increase of the proportion of rock asphalt, there is an increasing trend in the equivalent softening point, which means rock asphalt can improve asphalt's high-temperature stability.

③ A limited increase in the equivalent brittle point is observed with rock asphalt's modification, which means the addition of rock asphalt will slightly worsen asphalt's low-temperature stability.

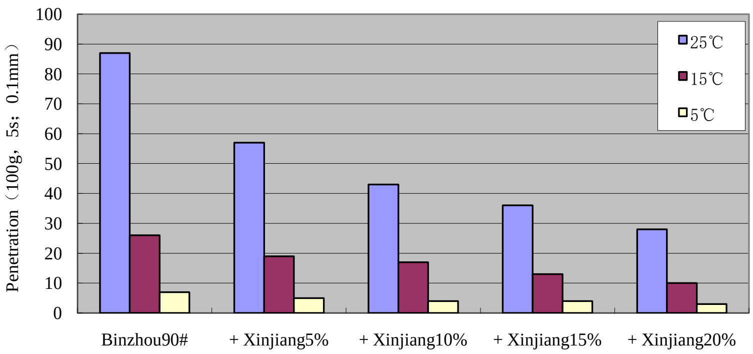

Fig. 1. Penetration variation of Binzhou 90# modified with rock asphalt

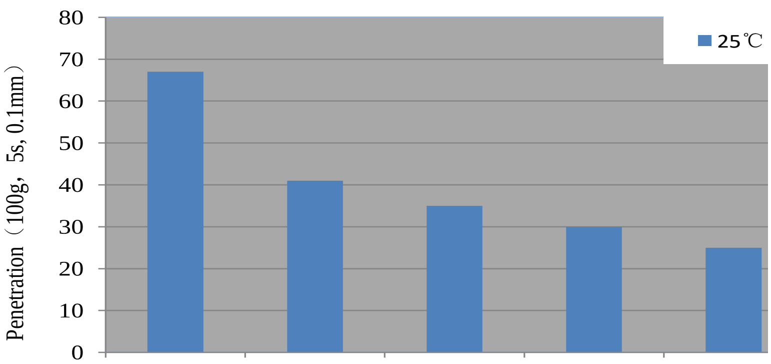

Fig. 2. Penetration variation of Maoming 70# modified by rock asphalt

From Fig.3~Fig.5, It can be seen from fig.14 to 17 that rock asphalt can remarkably reduce base bitumen's ductility before and after aging, and with the increase of rock asphalt, the asphalt's ductility reduced remarkably.

Softening point

As can be seen in Fig.6 and Fig.7:

① Rock asphalt can obviously elevate asphalt's softening point, so it's helpful to asphalt mixture's high-temperature stability and rut resistance.

② Asphalt's softening point elevates with the increase of rock asphalt content, but the increasing range reduces gradually. As 5% rock asphalt was added to Binzhou 90# bitumen asphalt for three times constantly, the increasing ranges of softening point were 5, 3 and 2°C.

Before and after asphalt's aging, the variation rule of the softening point changes with the rock asphalt's proportion as follows:

$$T_{R\&B} = 45.5 + 0.924p - 0.0160p^2 \qquad R^2 = 0.995$$

$$T_{R\&B} = 50.4 + 0.893p - 0.0114p^2 \qquad R^2 = 0.996$$

where **p** means the amount of rock asphalt (%).

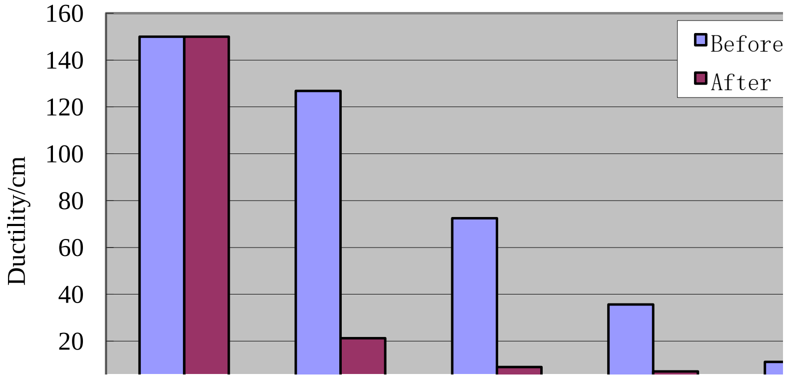

Fig. 3. The ductility of Binzhou 90# with different proportion of rock asphalt at 15°C

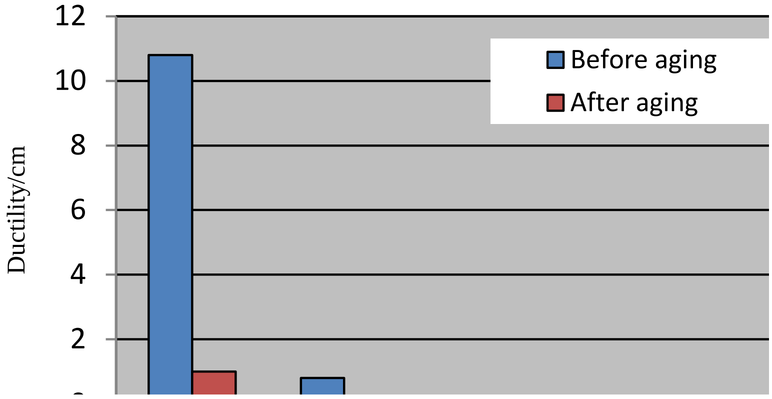

Fig. 4. The ductility of Binzhou 90# with different proportion of rock asphalt at 5°C

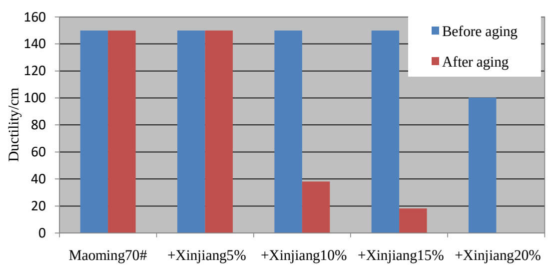

Fig. 5. The ductility of Maoming 70# with different proportion of rock asphalt at 25°C

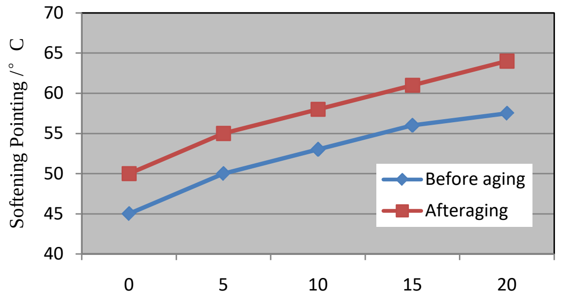

Fig. 6. Binzhou 90# with different proportion of rock asphalt's variation of softening point before and after aging

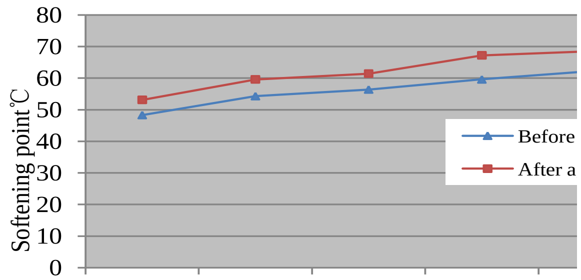

Fig. 7. Maoming 70# with different proportion of rock asphalt's variation of softening point before and after aging.

Asphalt mixture

Analysis of Marshall test results

As can be seen in Fig.8 and Fig.9:

① The modified asphalt mixture's stability is higher than that of base bitumen mixture and its Marshall Stability increased gradually with the increase of rock asphalt's proportion.

② The stability of Binzhou 90# asphalt mixture modified with 20% rock asphalt is the highest, but the stability's change doesn't show a linear relationship with the change of rock asphalt's blending ratio. The stability increased to the maximum amplitude, 13.4% when 5% Xinjiang rock asphalt was blended.

③ Respect to rock asphalt's changing content, the change rule of flow value is not obvious.

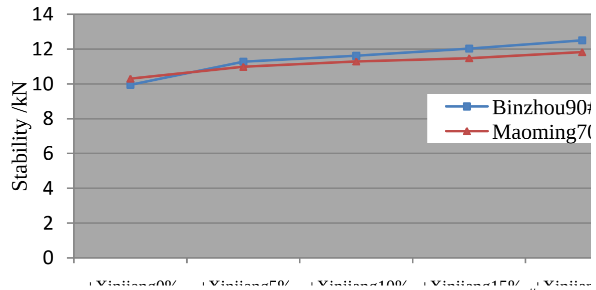

Fig. 8. Marshall Stability of Maoming 70# base bitumen with different proportion of rock stability.

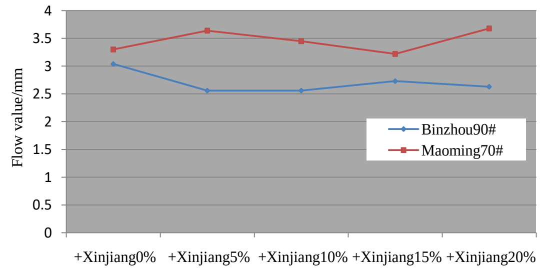

Fig. 9. Flow value of Maoming 70# base bitumen with different proportion of rock asphalt.

Rutting tests

As can be seen from fig.10:

① Modified with rock asphalt, Binzhou 90# base bitumen's dynamic stability and high-temperature rut resistance were improved obviously. For the maximum amount of rock asphalt (20%), asphalt's dynamic stability was increased to5.8 times the previous value and for the minimum (5%),to 2.1 times.

② Modified with rock asphalt, Maoming 70# and Binzhou 90# asphalt show the same rules, but with the increase of rock asphalt's content, the later increasing rangeof dynamic stability degree of Maoming 70# asphalt has reduces gradually. Thereforeit is not sure that Maoming 70# base bitumen's dynamic stability is higher than that of Binzhou 90# base bitumen when they are modified with the same amount of rock asphalt.

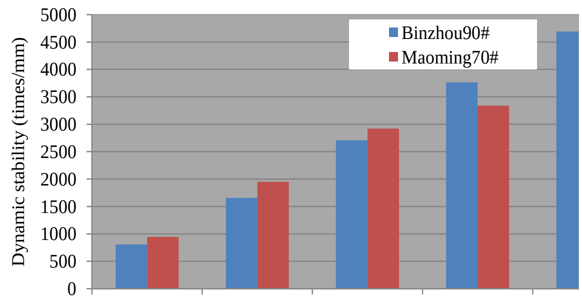

Fig. 10. Dynamic Stability of Asphalt Mixtures with Different Rock Asphalt Content.

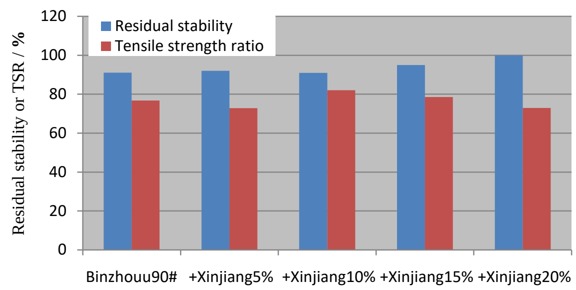

Fig. 11. Residual stability and freeze - thaw splitting intensity strength ratio of Binzhou 90# mixed with different contents of rock asphalt.

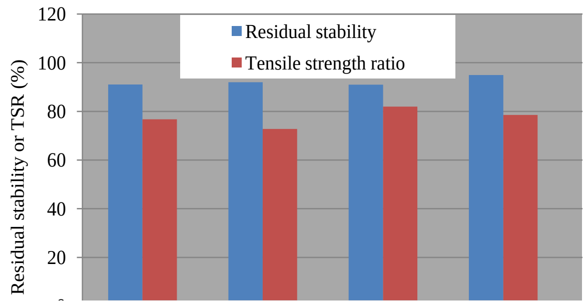

Fig. 12. Residual stability and freeze - thaw splitting intensity ratio of MaoMing 70# mixed with different contents of rock asphalt.

Water stability

From Fig.11 and Fig.12, it can be seen that Binzhou 90# and Maoming 70# base bitumen show similar rules when they are mixed with different proportions of rock asphalt:

① The residual stability and tensile strength ratio TSR of Binzhou 90# modified asphalt mixture are apparently higher than those of base bitumen, and the mixture's water stability increases with rock asphalt's addition. Modified with 5% Xinjiang rock asphalt, the residual stability of the mixture increased 3.9%, the tensile strength ratio increased 8.3%, and the increase extent can be bigger with more rock asphalt.

② After the water damage occurs, the residual strength of the Binzhou 90# asphalt modified with rock asphalt is significantly improved compared to that of base bitumen. For example, after freeze-thaw cycle, the residual tensile strength of base bitumen was 0.9MPa, while modified with10% rock asphalt, it could reach1.4MPa. It's the same with Maoming 70# asphalt modified with rock asphalt but with a certain fluctuation.

Analysis of low-temperature performance

Low-temperature test results of failure strength, failure strain and failure stiffness modulus of Binzhou 90# and Maoming 70# base bitumen mixture modified with Xinjiang rock asphaltare shown in Fig.13~Fig15.

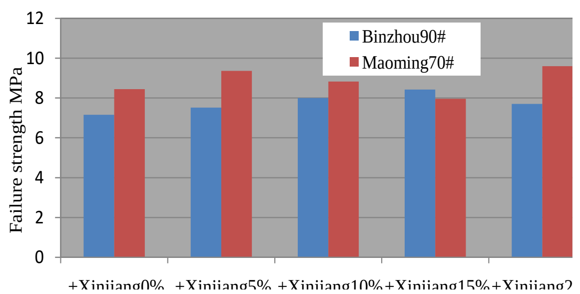

Fig. 13. Change of low temperature failure strength of modified asphalt

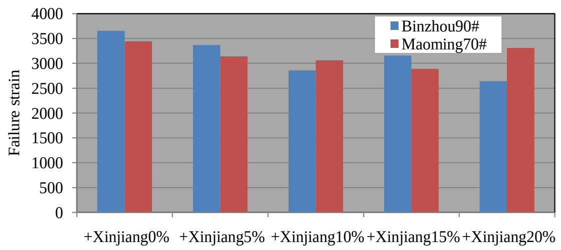

Fig. 14. Change of low temperature failure strain of modified asphalt

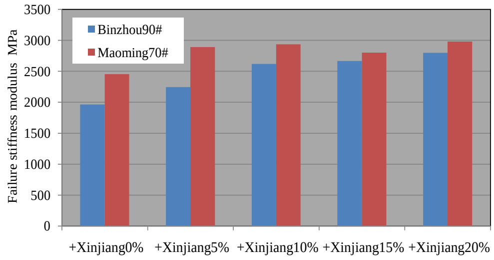

Fig. 15. Change of low temperature failure stiffness modulus of modified asphalt

① When the failure strain was used as the evaluation index, that of Binzhou 90# and Maoming 70# asphalt mixture was the largest, but after the modification of rock asphalt, it showed a decreasing trend, indicating that asphalt mixture's low-temperature performance became worse. With the increase of the amount of rock asphalt, the low-temperature damage strain decreased gradually.

② In terms of failure strength index, after rock asphalt's addition, Binzhou 90 # asphalt mixture's ultimate bending strength at low temperature became higher.

CONCLUSION

1. After rock asphalt's modifying, base bitumen's penetration decreases and its softening point, rutting factor $G^*/\sin\delta$ and elastic component increase , contributing to improving asphalt's high-temperature deformation resistance and fatigue performance.

2. Modified with rock asphalt, asphalt's low-temperature ductility decreases. It is shown that the addition of rock asphalt will improve the high temperature performance, but at the same time will reduce the low temperature crack resistance of asphalt. The optimum amount of rock asphalt is 5% to 15%.

3. Modified asphalt mixture with rock asphalt has higher Marshall Stability, and the greater the amount of rock asphalt content is, the better asphalt's high-temperature rut resistance becomes.

4. The residual stability and split strength

ratio of modified asphalt mixture are both obviously higher than those of base bitumen, and increases with the addition of rock asphalt content, that is, the modification can improve mixture's water resistance.

5. Rock asphalt's modification can obviously improve asphalt mixture's mechanical strength and fatigue resistance and those will increase with the addition of rock asphalt content.

6. Modified asphalt's softening point has good correlations with modified mixture's dynamic stability, indicating that the improvement in asphalt mixture performance comes from the modification ock asphalt.

7. With addition of rock asphalt mixture's low-temperature damage strain may decrease slightly.

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ЗА ЕФЕКТИВНОСТ И ОЦЕНКАТА НА ШИСТОАСФАЛТ, МОДИФИЦИРАН АСФАЛТ И СМЕСИ

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(Резюме)

За да се изучат правилата за изменение на свойствата на модифициран асфалт с шистоасфалт и техните смеси, Binzhou 90$^{\#}$ асфалтов битум и Maoming 70$^{\#}$ асфалтов битум са модифицирани съответно с 5, 10, 15 и 20% асфалтови шисти от Синцзян. Промяната на свойствата на модифицирания асфалт се изследва чрез конвенционалните показатели на системата за градуиране на индекса за класификация и DSR, BBR, както и експерименти върху модифициран асфалт, класифициран като AC-13, свойства при висока температура, устойчивост на вода, нискотемпературна устойчивост на пукнатини и умора. Резултатите показват, че модификаторът на шистоасфалта е полезен за подобряване на работата на асфалта при висока температура, но може да повлияе и на работата при ниска температура. Оптималният обхват на съдържанието на шистоасфалт трябва да се контролира от 5 ~ 15%. Подобряването на характеристиките на модифицирания асфалт е полезно за високотемпературните характеристики, устойчивостта на вода и умората на неговата смес, но ниско температурните характеристики могат да се влошат в тесен диапазон.