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The Study of Water Stability for SBS and Polyacrylate Composite Modified Asphalt Mixture

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Abstract:
Polyacrylate (Polyacrylate, called PAE) is a kind of thermoplastic polymer latex, which is easy to form a waterproof membrane and has greater adhesion ,always be used in concrete to enhance its ability to resist water corrosion.SBS is an inorganic modifier for modified asphalt mixture will help to improve the high and low temperature stability and other road performance, ect.However,its ability to enhanced asphalt mixture's resistance for water damage is not obvious. In order to research the two composite modified asphalt mixture's resistance effects to water damage , the Marshall Stability Test and Fort Kentucky Flooding Scattering Experiments were used on asphalt mixtures, SBS modified asphalt mixture and composite modified asphalt mixture and the effect of different composite modified PAE content were studied. The results showed that: PAE can significantly improve the water stability of asphalt mixture, what's more, with the increase use of PAE,the mass loss rate of asphalt mixture decreases steadily.
Key words: Asphalt mixture; Composite modified; Water stability;SBS; PAE

I. Introduction

In recent years, the greenhouse effect on the global environment are becoming more and more obvious. Hot weather and also the rainy weather are the major natural environment challenges that the asphalt concrete pavement are facing. However, as a viscoelastic material, asphalt is hydrophobic, which undermines the asphalt concrete pavement's ability of resisting water damage. Because of the water damage, asphalt and aggregate will peel off, which may lead to further damage to the pavement structure. And water damage to the pavement will become worse under the influence of hot and humid environment (high temperature and rainfall). As a thermoplastic polymer, PAE have strong adhesion and also can form a waterproof membrane. And, PAE is widely used in cement concrete to improve its strength and corrosion resistance, but seldom used in modification application study on resistance to water damage in asphalt concrete. Therefore, it's very significant for us to study further on PAE's application in stability of modified asphalt mixture and the optimal dosage of PAE.

For this reason, this paper conducts Marshall stability test and Fort Kentucky flooding scattering test on asphalt concrete, sbs modified asphalt concrete, PAE and SBS composite modified asphalt concrete (the following are referred as A-type, B-type and C-type bituminous concrete and C-type asphalt concrete have 5 different dosages of PAE, which were 4%, 6%, 8%, 10%,and 12%, respectively marked as the C1, C2, C3, C4 and C5.) ,respectively.

II. Raw materials

2.1 Stone materials and asphalt

In this paper, we introduce AC-20-grade asphalt concrete, in which stone materials are made of clean and un-weathered metamorphic sandstone and asphalt is shell 90# high quality bitumen. Asphalt technical indicators are shown in Table 2.1. The stone materials and asphalt are shown in figure 2.2.

Tab2.1 basic technical indexes of asphalt

indicators	25℃ penetration/（0.1mm）	10℃Ductility/（cm）	Softening Point /（℃）	60℃Viscosity/（Pa·s）
Test result	86.3	31.6	47.0	163

Fig2.1 quality meta sandstone

Fig2.2 asphalt of shell 90

2.2 Diatomaceous and poly acrylate emulsion

Here, we use Jilin-produced SBS with high quality and polyacrylate is emulsified polyacrylate emulsion. Fig2.3 and Fig2.4 show the SBS and polyacrylate latex, respectively.

Fig2.3 the modifier of SBS

Fig2.4 the modifier of Polyacrylate latex

III. proportion of Asphalt Mixure Designing

According to highway asphalt and asphalt testing procedures (JTG E20-2011), we introduce standard Marshall test to design proportion of asphalt mixure. And, we adopt wet mixed method for asphalt modification, stirring and incorporating SBS Modified Asphalt(We can determine the best SBS production in the region is 15% amount of asphalt content by asphalt index). The basic technical indicators of SBS modified asphalt are shown in Table 3.1

Tab3.1 the basic technical indicators of SBS modified asphalt

indicators	25℃ penetration/（0.1mm）	10℃Ductility/（cm）	Softening Point /（℃）	50℃Viscosity/（Pa·s）
Test results	99.1	79.9	78.0	12972

According to "asphalt pavement design and technical specifications" (JTG D50-2006) and "Highway Engineering aggregate testing procedures" (JTGE42-2005),we study on modified asphalt and proportion of asphalt mixture designing. First, we obtain the pass rate of different stall feeding by sieving, then draw out aggregate gradation curve and determine aggregate gradation. After that, we test the mechanical properties of graded aggregates and then determine the proportion of asphalt mixture based on Marshall asphalt mixture design method. Table 3.2 shows the basic mechanical properties of aggregates and proportion of asphalt mixture.

Tab3.2 basic mechanical properties of aggregates and proportion of asphalt mixture

Graded aggregates indicators	Crushing value（%）	Flakiness content（%）	Apparent density（g/cm^3）	Bulk density（g/cm^3）
Testing results	17.5	4.0	2.813	1.825

Sieve size（mm）	26.5	19	16.0	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Graded ceiling	100	100	91	80	73	56	44	33	24	17	14	6
Synthetic grading	100	92.3	85.4	76.1	58.0	40.5	25.2	20.9	13.3	7.5	6.3	5.1
Graded lower limit	100	89	78	62	50	26	15	12	8	5	4	3

Asphalt types and ratio（%）		
	Asphalt	4.1%
	SBS Modified Asphalt	3.9%

IV. Experimental Design and experimental results

4.1 Marshall stability test

First, we do residual stability test according to results of proportion of asphalt mixture, then two Marshall groups are formed by A-type, B-type, C1-type, C2-type, C3-type, C4-type, and C5-type(one group is to do the standard Marshall test, another group is to do immersion Marshall test. Four specimens are set from each group, the results are averaged).

Experimental conditions: loading rate 50mm / min, specimen height 63.5 ± 1.3mm.The experiment requires specimens being immersed in 60 ℃ constant temperature for 48h. Marshall test specimen measured indicators as well as the experimental results and immersion Marshall Marshall experimental results are shown in Table 4.1.

Tab 4.1 the water stability of Marshall specimen

Mixture type	Porosity (%)	VMA (%)	Saturation (%)	Standard Marshall stability \(KN)	Immersion Marshall stability (KN)	Residual stability (%)
A-type	6.1	59.9	59.3	10.4	8.3	79.9
B-type	5.9	60.3	60.4	11.6	10.1	87.2
C1-type	5.6	62.1	60.9	12.1	11.4	94.3
C2-type	5.5	62.9	61.5	13.9	11.7	94.8
C3-type	5.2	63.7	61.4	13.9	13..6	97.6
C4-type	4.5	64.1	61.5	14.4	14..1	97.7
C5-type	4.4	64.7	61.00	14.6	14..3	98.3

According to Marshall stability test results, plot the relationship curve of PAE content and stability of asphalt residues., including the stability of (y) and PAE residual asphalt content (x) complying with the formula,

$$y = -825.48x^2 + 187.93x + 87.348$$

, where the correlation coefficient $R^2 = 0.9809$. Firgure4.1 shows the curve.

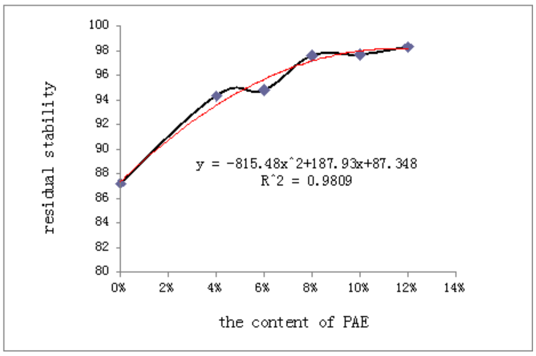

Fig4.1 the relation between PAE content and residual stability

From table4.1 and figure 4.1, the results show:

(1) Comparing the asphalt stability and residual stability of A-type, B-type, and C-type, we find that the SBS modified asphalt mixture have better asphalt stability and residual stability than asphalt mixture. And asphalt concrete that incorporates with PAE have the largest asphalt stability and residual stability, so PAE plays an significant role in improving the water stability of asphalt mixture. (2) For B-type and C-type asphalt concrete, PAE content were respectively 0%, 4%, 6%, 8%, 10% and 12%, and the corresponding residual stability of asphalt mixture ranges from 79.9% to 98.2% and it shows the relationship of the corresponding growth. Therefore, asphalt's ability of resisting to water damage enhances with increasing PAE content. What's more, as the PAE content increases from 6% to 8%, the residual stability shows stepped growth. And it begins to have less obvious effect on the residual stability with 8% PAE content or more. Therefore, the modified water stability has the most obvious effect with 8% PAE content, thus from an economic perspective, the recommended PAE content is 8%. (3) Plot the relationship between PAE content and residual stability. From figure4.1, we can find that effect of PAE content on residual stability

presents a quadratic curve, and fitting correlation coefficient $R^2 = 0.9809$. The fitting curve has an excellent correlation. This also indirectly shows that asphalt mixture water stability has the best modification effect with the recommended 8% PAE content.

4.2 Fort Kentucky flooding scattering test

According to China's "highway asphalt and asphalt testing procedures" (JTG E20-2011), we obtain Marshall specimens from seven types of asphalt mixture (four Marshall specimens from each group and the results are averaged) and then do Fort Kentucky flooding scattering test.

Experimental procedures: standard double-sided compaction method for making Marshall specimen after fostering, then release mold; all specimens are placed in 60 ℃water bath regimen for 48 hours, then placed at room temperature for 24 hours, and weigh the specimen and get the weight of m0 after 24h ; Put the specimens in Los Angeles testing machine, start the scattering experiments (turn times for 300 rpm, speed 33r / min), after that, weigh the test specimen and get the weight of m1; finally calculate the scattering mass loss using Equation 4.2

$$\Delta S = \frac{m_0 - m_1}{m_0} \times 100 \quad \cdots\cdots\cdots \text{Equation 4.2}$$

ΔS –mass loss rate

m_0—specimen weight before the experiment（kg） ;

m_1—specimen weight after the experiment（kg）

The result of Kentucky flying test is shown in Table4.2.

Tab4.2 the result of Kentucky flying test

Mixture type	m_0（Kg）	m_1（Kg）	ΔS （%）
A-type	1196.6	819.7	29.5
B-type	1204.3	965.8	18.8
C1-type	1204.1	1082.5	10.2
C2-type	1205.4	1074.0	11.1
C3-type	1205.6	1109.2	8..2
C4-type	1205.9	1110.6	7.8
C5-type	1207.1	1114.2	7.6

Table4.2. shows that : (1)Comparing Kentucky Fort flooding scattering loss rate of A-type, B-type and C-type asphalt, we can find that the mass loss rate of asphalt mixture can reach to 31.5% after the soaking scattering test. The water stability of SBS modified asphalt mixture is improved and the mass loss rate is 19.8%. And asphalt mixture with PAE have the smallest mass loss rate. Therefore, PAE has a significant effect on improving the asphalt mixture's ability to resist to water damage. (2) Considering B-type and C-type bituminous concrete mass loss rate, we find that the scattering loss rate decreases with the increasing content of PAE; As PAE content decreases from 6% to 8% , the scattering loss rate also decreases to 2.9 %and the scattering loss rate almost doesn't change when the PAE content exceeds 8%. Therefore, the asphalt mixture's ability of resisting to water damage enhances with PAE increasing and modifying effect is relatively obvious with 8%PAE, which matches with the experimental results of residual stability.

V. Conclusion

After conducting asphalt mixture Marshall Stability Test and Fort Kentucky flooding scattering test on asphalt concrete, SBS modified asphalt concrete, PAE and SBS modified asphalt concrete, we can conclude that:

(1) Residual stability test and Fort Kentucky flooding scattering test can better simulate asphalt's

engineering application conditions, which can effectively evaluate the PAE water stability for asphalt modification. The stability of residual asphalt enhances with PAE content increasing. It also reduce the scattering loss. Therefore, PAE has a significant effect on improving the asphalt mixture's water stability.

(2) The relationship curve of PAE content (x) and stability of asphalt residues(y) complies with the following formula,

$$y = -825.48x^2 + 187.93x + 87.348$$

, where the correlation coefficient $R^2 = 0.9809$.

（3）The residual stability of asphalt mixture ranges from 79.9% to 98.2% as PAE content is between 0 and12%. What's more, as the PAE content increases from 6% to 8%, the residual stability shows stepped growth. And it begins to have less obvious effect on the residual stability with 8% PAE content or more. Therefore, the modified water stability has the most obvious effect with 8% PAE content, thus from an economic perspective, the recommended PAE content is 8%.

(4) From Fort Kentucky flooding scattering test, we can find that the scattering loss rate also decreases to 2.9 % as PAE content decreases from 6% to 8%, and the scattering loss rate almost doesn't change when the PAE content exceeds 8%. Therefore, the asphalt mixture's ability of resisting to water damage enhances with PAE increasing and modifying effect is relatively obvious with 8%PAE, which matches with the experimental results of residual stability.

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