Study on the Storage Stability of WMA Modified Asphalt

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ABSTRACT: In recent years, warm mix asphalt mixture (WMA) receives much concern for its good environmental performance and Sasobit is the widely used modifier in WMA. The modified asphalt was prepared by adding polymer Sasobit into base asphalt and the segregation tests were carried on under different factors. And then the storage stability of the modified asphalts was analyzed by the difference of softening point between the top part and bottom part after segregation tests under different mixing amount of Sasobit, storage time and storage temperature. The stability of the modified asphalt is good with different mixing amount of Sasobit through the segregation tests. The segregation test results of modified asphalt with 3% Sasobit at 100℃~163℃ were analyzed and the results show that the storage stability at low temperature is better than that at high temperature. In addition, the segregation tests of modified asphalt with 3% Sasobit from one day to seven days were carried out and the results show that the storage stability for three days is the best.

KEY WORDS: WMA, modified asphalt, segregation test, storage stability.

1 INTRODUCTION

The traditional HMA (Hot Mixture Asphalt) is the most widely used at present, which needs the higher temperature in the process of mixing, paving and rolling. A large number of energy is consumed and a mass of smoke and harmful gases (e.g. CO, CO_2, SO_2 and NO_x, etc.) are produced during the production and construction which cause serious environmental problems and is bad for the technologists as well. A new kind of environmental warm mix asphalt (WMA) was developed to replace the traditional hot mix asphalt mixture (HMA) as the environmental problems received more and more attention early in 1995 (Harrison and Christodulaki 2000). Warm mix asphalt mixture can be mixed and constructed at relatively low temperature while the construction workability and the road performances are the same as HMA. In this paper, adding polymer Sasobit into base asphalt is one kind of the technologies for WMA (Graham and Hurley 2005-2006).

The storage stability is of vital importance for polymer modified asphalt. Many researchers studied it and most of the researches were for the storage stability of SBS polymer modified asphalt. Moreover, the storage stability was improved by adding various stabilizer (Sun and Lu 2003, Cong et al. 2002, Wang et al. 2007, Wen et al. 2002). Meanwhile, the storage stabilities of polymer modified asphalt were studied for SEBS, EA, EBA and LDPE through different ways, respectively (Ouyang et al. 2006, Iqbal et al. 2006, Ouyang et al. 2006).

The storage stability of polymer modified asphalt is that there are no segregation or degradation for the polymer modified asphalt in the process of production, storage and appliance. Two phases materials with similar polarity, solubility parameter, surface tension, molecular weight and viscosity can achieve good blending according to the relevant theories about polymer blending (Nishimoto et al. 1991). The uniform blending can't be achieved through permeation and diffusion effect at the molecular level because there is a wide difference between the polymer modifier and asphalt in the molecular weight, viscosity and surface tension. Therefore, the phase separation occurs easily for the polymer and asphalt of the polymer modified asphalt in the process of storage, transportation and construction and the performances of modified asphalt falls. The influences from the mixing amount of Sasobit, storage temperature and storage time on the segregation of modified asphalt were investigated by adding Sasobit into the base asphalt, and the storage stability of the base asphalt and Sasobit was studied.

2 TEST PROCESS

2.1 Test material

Base asphalt: Shell No. 90 base asphalt and its characteristics are shown in Table 1. Modifier: Sasobit and its physical indexes are shown in Table 2.

Table 1: Properties of the base asphalt.

Technical index	Unit	Technical requirements	Detection results	Test methods
Penetration(25℃)	0.1mm	80~100	83	T0604-2000
Penetration index	…	-1.8~+1.0	-1.29	T0604-2000
Ductility(15℃)	cm	≥100	>150	T0605-1993
Ductility(10℃)	cm	≥20	30	T0605-1993
Softening point(5℃)	℃	≥45	46	T0606-2000
Viscosity(60℃)	Pa·s	≥160	160	T0625-2000
Flash point	℃	≥245	325	T0611-1993
Density(15℃)	g/cm^3	Measured records	1.034	T0603-2000
Thin film oven test (TFOT)(163℃, 5h)				T0609-1993
Mass loss	%	≤±0.8	0.2	T0609-1993
Penetration ratio(25℃)	%	≥57	60	T0604-2000
Ductility(10℃)	cm	≥8	8	T0605-1993

Table 2: The physical indexes of Sasobit.

Performance indexes	Unit	Typical value
Solidification point	℃	100
Flash point	℃	about 290
Viscosity(135℃)	10^{-3}Pa·s	12
Penetration(25℃)	0.1mm	<1
Density(25℃)	g/cm^3	0.94
Appearance	White, spherical, approximately 3mm in particle size	

2.2 Specimen preparation

The solidifying point of the Sasobit modifier applied in this paper is 100℃, and it is liquid when the temperature is above 115℃. Then the Sasobit can be dissolved in asphalt completely if the asphalt temperature is above 115℃. Therefore, the Sasobit was added into base asphalt whose temperature is 120℃ and stirred for about 30 minutes with a glass rod in preparing the modified asphalt. And the stir is easier as the asphalt temperature rises.

2.3 Test methods

The segregation tests of polymer modified asphalt are carried out according to "Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering" T0661-2000. Firstly, the 50g modified asphalt was filled into a glass tube (25mm×200mm) whose inner wall was brushed by the glycerin and talcum powder sealing liquid. The glass tube was sealed and put into the oven whose temperature is 163℃ and stewed for 48h. Subsequently, the glass tube was taken out and be frozen for more than 4h in the refrigerator keeping it vertical. The glass tube was taken out when the modified asphalt was solidified completely. Then the asphalt in the glass tube is divided evenly into three parts. Finally, the modified asphalt in the glass tube was divided into three sections, the top and the bottom parts were selected to measure their softening points and calculate their difference values for evaluating the segregation degree, which was shown in Figure 1.

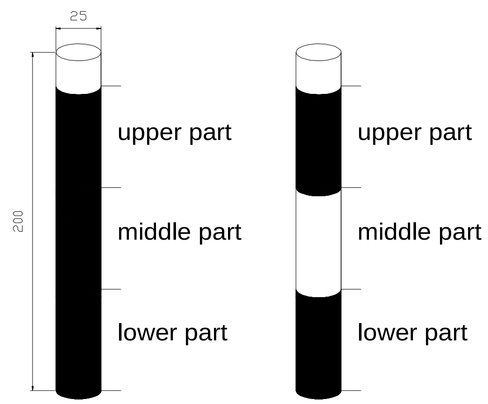

Figure 1: Segregation test.

2.4 Research scope

The segregation tests were carried out under different mixing amount of Sasobit, different storage temperature (100℃, 120℃, 140℃ and 163℃) and different storage time (1d, 2d, 3d, 5d and 7d) with the same mixing amount of Sasobit for the modified asphalt in this paper.

3 ANALYSIS ON TEST RESULTS

3.1 Influences on the storage stability of modified asphalt with different mixing amount of Sasobit

1%~5% Sasobit was added into Shell No. 90 base asphalt and the segregation tests were carried out at 163℃ for 48h. The results are shown in Table 3.

Table 3: The segregation test results with different mixing amount of Sasobit.

Mixing amount of Sasobit (%)	Original softening point(℃)	Softening point after segregation tests(℃)		
		Upside	Bottom	Difference values
1	51.2	53.2	52.6	0.6
2	62.2	64.5	64.9	-0.35
3	72.9	76.2	74.9	1.3
4	82.6	82.5	81.9	0.55
5	85.4	86.8	86.7	0.15

The difference values of the softening points are less than 2.5℃ with 1%~5% Sasobit modified asphalt after segregation in line with the specification requirements and the storage stability is qualified from Table 3.

The histogram and scatterplot are drawn as shown in Figure 2 and Figure 3 with the results in Table 3. It can be found that the softening points of modified asphalt rise gradually as the content mixing amount of Sasobit increases, which means that the high temperature stability of asphalt reinforces from Figure 2. Meanwhile, it can also be found that the softening points of the modified asphalt in upper part and lower part fluctuate around the initial softening points after segregation (the variation range is 0.18%~4.53%) without excessive fluctuation, which indicates that the asphalt properties are not changed greatly before and after segregation even if the modified asphalt segregates. In addition, the difference values of the softening points in upper part and lower part exhibit an unobvious regularity as the mixing amount of Sasobit increases from Figure 3. The softening points in the upper part and lower part change small after segregation along with the mixing amount of Sasobit increases from 1% to 5% and the storage stability with 3% Sasobit is poorer than other mixing amount.

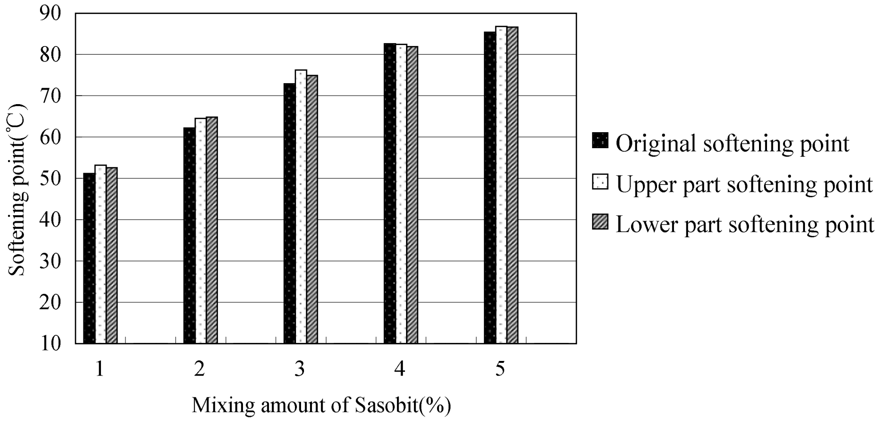

Figure 2: Softening points of modified asphalts with different mixing amount of Sasobit before and after segregation tests.

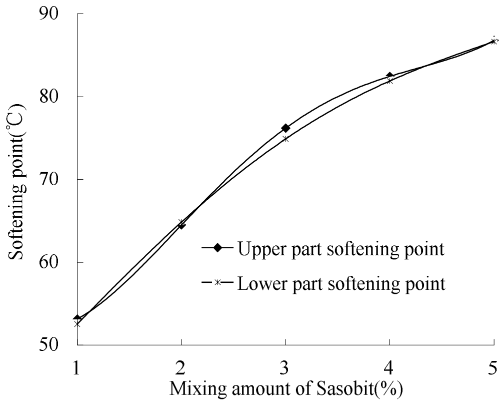

Figure 3: Influence on the storage stability of modified asphalt under different mixing amount of Sasobit.

3.2 Influences on the storage stability of modified asphalt under different storage time

The modified asphalt with 3% Sasobit was selected for 1d, 2d, 3d, 5d and 7d segregation tests at 163 ℃. The tests results are shown in Table 4.

Table 4: The segregation test results with different storage time.

Storage time(d)	Upside(℃)	Bottom(℃)	Difference values (℃)
1	74.6	77.0	-2.4
2	76.2	74.9	1.3
3	75.2	74.9	0.3
5	76.2	77.1	-0.9
7	76.2	74.6	1.7

The modified asphalt with 3% Sasobit was tested under different storage time. Then it can be found that the difference values of the softening points meet the specification requirements without segregation from Table 4.

The histogram and scatterplot are drawn as shown in Figure 4 and Figure 5 with the results in Table 4. It can be found that the softening points of modified asphalt in upper part and lower part after segregation are higher than the initial softening points, which was possibly caused by aging under high temperature from Figure 4. The increase range of the softening point in upper part is 2.33%~4.53% and the increase range of the softening point in lower part is 2.26%~5.76% compared with the initial softening points. Therefore, the fluctuation range is small and the segregation of the Sasobit modified asphalt is unobvious. It can also be found that the storage stability of the modified asphalt with 3d storage time is the best and the storage stability decreases if the storage time is not 3d from Figure 5 and Table 4, which is of important directive significance in the preparation and appliance of the modified asphalt. And the softening point in upper part increases and the softening point in lower part decreases over the storage time, but the difference values of the softening points aren't regular.

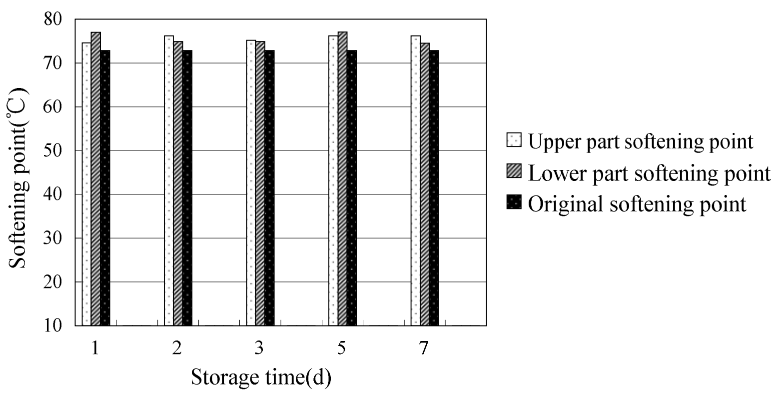

Figure 4: Softening points of modified asphalts with different storage time before and after segregation tests.

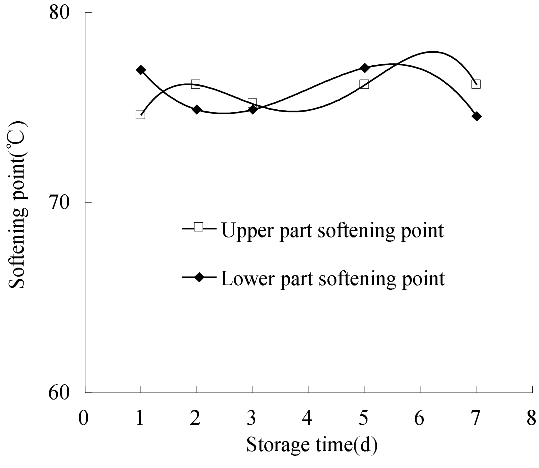

Figure 5: Influence on the storage stability of modified asphalt under different storage time.

3.3 Influences on the storage stability of modified asphalt under different storage temperature

The modified asphalt with 3% Sasobit was selected to store for 48h at 100℃, 120℃, 140℃ and 163℃ and the segregation tests were carried out. The results are shown in Table 5.

Table 5: The segregation test results with different storage temperature.

Temperature(℃)	Upside (℃)	Bottom(℃)	Difference values(℃)
100	74.9	74.75	0.15
120	75.6	74.6	1
140	77.1	74.1	3
163	76.2	74.9	1.3

It can be found that the segregations of the modified asphalt are obvious with the same kind and mixing amount of Sasobit under different storage time from Table 5. The difference value of the softening points at 140℃ is 3℃ exceeding the standard requirements and causing segregation, and the stabilities of the modified asphalt are good under other temperatures.

The histogram and scatterplot are drawn as shown in Figure 6 and Figure 7 with the results in Table 5. It can be found that the fluctuation range of the softening points in upper part and lower part at 140℃ and 163℃ is larger than that at 100℃ and 120℃ after segregation, and the both softening points are higher than the initial one from Figure 6. Moreover, it is obvious that the storage stability at low temperature is better than that at high temperature from Figure 7. The reason for the above result is that the heat movements of Sasobit molecules and base asphalt are accelerated as temperature rises. Sasobit molecules rise gradually while base asphalt declines gradually under gravity because the density of Sasobit is smaller than that of base asphalt at high temperature. Thus the swelling between the modifier particles and base asphalt is affected and the swelled modifier particles surface is not able to fully absorb the asphalt components that have good affinity to modifier. Then the interface absorbed layer is caused to be thin and the distance between particles increases, and the mutual influence declines. Hence, a fine interface absorbed layer can not be formed. However, the quality of the interface absorbed layer is a key factor to determine the modified asphalt performance. As a result, the segregation at high temperature is more obvious than that at low temperature.

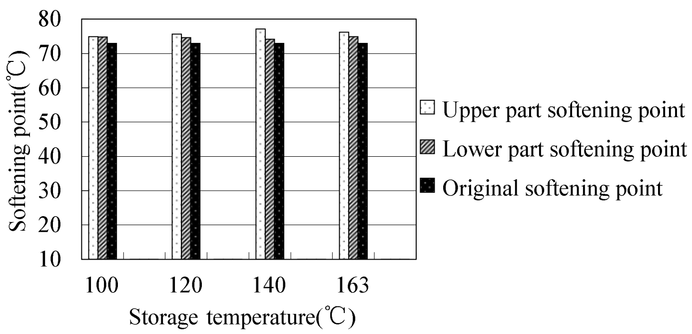

Figure 6: Softening points of modified asphalts with different storage temperature before and after segregation tests.

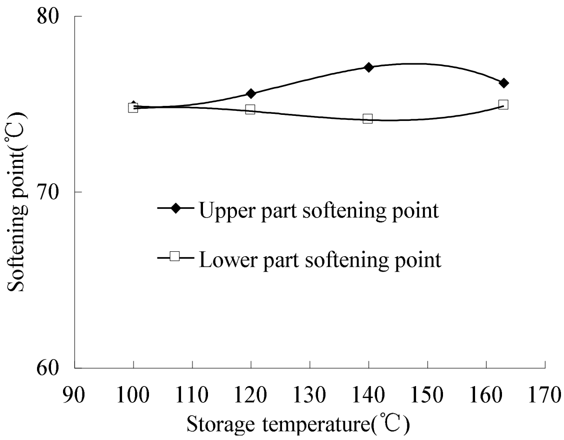

Figure 7: Influence on the storage stability of modified asphalt under different storage temperature.

4 DISCUSSIONS

The melting point of Sasobit asphalt modifier is about 100℃ and it can be completely melt in asphalt when the asphalt temperature is above 115℃. Sasobit can be scattered in asphalt steadily only by means of simple mechanical agitation without special equipment under the heating conditions overcoming the faults of easy segregation and difficult mixing for the traditional asphalt modifier. The appearance and micro-cosmic morphology of Sasobit modifier under polarizing microscope are shown in Figure 8 and Figure 9.

There are four components in asphalt which are asphaltine, colloid, aromatic constituents and saturated components by four group analysis method for asphalt. The saturated components are composed of straight chain or branched-chain aliphatic hydrocarbon, alkyl cyclane and alkyl aromatics including waxiness and non-waxiness saturates. However, Sasobit is a kind of polyolefin asphalt modifier whose chemical components are synthetical long chain saturated hydrocarbons. Sasobit is widely used in asphalt mixture due to its unique chemical compositions with perfect performance.

Figure 8: Sasobit wax.

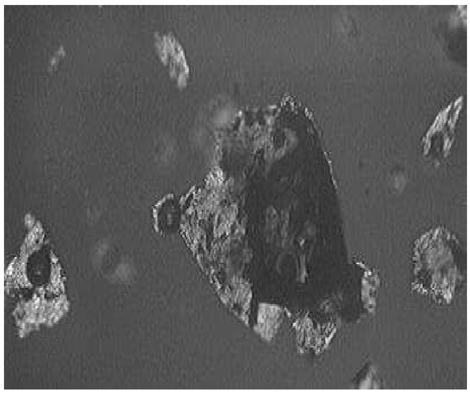

Figure 9: The metallograph of Sasobit wax.

In the process of preparing Sasobit modified asphalt, the saturated components with similar structure to Sasobit in asphalt are absorbed at high temperature by Sasobit after Sasobit is added into the heated asphalt and the modifier swells because the base asphalt components are absorbed. The unfolding degree of macromolecules is bigger in the interface, so it is easy to form stable solution without segregation after Sasobit dissolves in asphalt. Furthermore, most of the saturated components are ceryl or oil base molecules, or a part of them. The polarity compositions in asphalt are improved relatively because the modifier absorbed part of saturated components which are similar to those in base asphalt in structure. And Sasobit should be swelled fully in the process of preparing Sasobit modified asphalt. The swelling degree is larger for the modifier indicates that the better affinity between asphalt and modifier is obtained. The swelling degree of modifier decreases as the mixing amount increases due to the number of components in asphalt which can make the modifier swell is limited. However, the stability of modified asphalt is good as the mixing amount of Sasobit increases from 1% to 5%, which indicates that the modifier is swelled fully in this paper.

It is certain that more components in asphalt with good affinity to modifier are absorbed by the surface of the swelled modifier particles forming a surface absorbed layer. As a result, it is more favourable to form a good interface between polymer and asphalt as the swelling degree is larger for the asphalt modifier. Meanwhile, the thickness of interface absorbed layer is determined by the swelling degree. The thickness of interface absorbed layer is larger and then the interaction between the adjacent polymer modifier particles is greater. The swelled Sasobit and base asphalt form a blending system under high temperature. But the system is not stable due to the thermodynamics and kinetics effect and the phase may separate under gravity. In the static condition, the associating asphalt moves to the bottom of the blending system by gravity and Sasobit modifier rises slowly, which leads to the segregation. Asphalt liquidity increases as the storage temperature rises and the interaction between modifier particles reduces. Nevertheless, Sasobit's density is smaller than that of asphalt, so the Sasobit segregation degree is greater under gravity namely the segregation is much more obvious. The segregation test results of Sasobit modified asphalt under different storage time are in line with the above situation in this paper.

When the temperature is below 90℃, Sasobit and the saturated components which are partly absorbed and dissolved by Sasobit crystallize and dissolve out together gradually because the melting point of Sasobit is high. Then the net lattice structure is formed in asphalt and the distance between the molecular chains of modified agents becomes larger, thus the saturated oil and wax components are locked. Therefore, the softening point and strength of asphalt are enhanced and the asphalt stability is increased. Besides, the rutting resistance performance is improved within the pavement use temperature.

The phase segregation degree of Sasobit modified asphalt is relative to the mixing amount and is affected by the storage conditions such as time and temperature. Meanwhile, the base asphalt components, the polymer components and the interface absorbed layer formed by base asphalt and polymer are the important factors which influence the storage stability of Sasobit modified asphalt.

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REFERENCES

Cong, Y.F., Huang, W., Liao, K.J., Zhai, Y.C., 2005. *Study on Storage Stability of SBS Modified Asphalt*. Mental Health Nrusing, 23(1): 39-46.

Harrison, T., Christodulaki L., 2000. *Innovative Processes in Asphalt Production and Application Strengthening Asphalt's Position in Helping to Build a Better World*. First International Conference: World of Asphalt Pavements, Sydney.

Hurley G.C., Prowell B.D., 2005. *Evaluation of Sasobit for Use in Warm Mix Aasphalt*. NCAT report 05-06: 7-9.

Iqbal, M.H., Hussein, I.A., Al-Abdul Wahhab, H.I.; Amin, M.B., 2006. *Rheological Investigation of the Influence of Acrylate Polymers on the Modification of Asphalt*. Journal of Applied Polymer Science, 102(4): 3446-3456.

Nishimoto, M., Keskkula, H., Paul, D.R., Garcia-Morales, M., Partal, P., Navarro, F.J., 1991. *Miscibility of Polycarbonate with Methyl Methacrylate-based Copolymers*. Polymer, 32(7): 1274-1283.

Ouyang, C.F., Wang, S.F., Zhang, Y., 2006. *Low-density Polyethylene/silica Compound Modified Asphalts with High-temperature Storage Stability*. Journal of Applied Polymer Science, 101(1): 472-479.

Ouyang, C.F., Wang, S.F., Zhang, Y., Zhang, Y.X., 2006. *Thermo-theological Properties and Storage Stability of SEBS/kaolinite Clay Compound Modified Asphalts*. European Polymer Journal, 42(2): 446-457.

Sun, D.Q., Lu, W.M., 2003. *Investigation and Improvement of Storage Stability of SBS Modified Asphallt*. Petroleum Science and Technology, 21(5-6): 901-910.

Wang, Q., Liao, M.Y., Wang, Y.R., 2007. *Characterization of End-functionalized Styrene-butadiene-styrene Copolymers and Their Application in Modified Asphalt*. Journal of Applied Polymer Science, 103(1): 8-16.

Wen, G., Zhang, Y., Zhang, Y.X., Sun, K., Fan, Y.Z., 2002. *Rheological Characterization of Storage-stable SBS-modified Asphalts*. Polymer Testing, 21(3): 295-302.