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Evaluation of the Long-term Properties of Sasobit Modified Asphalt

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Abstract: In this study, Sasobit, as an asphalt modifier, was blended into two base asphalts— Pen 60/80 asphalt and SBS modified asphalt. The additional content of Sasobit was 2%, 3%, 4% and 5% by mass of asphalt. The Rolling Thin Film Oven test (RTFO) and the Pressure Aging Vessel test (PAV) simulate the asphalt's short-term aging and long-term aging separately. Two sets of evaluating systems (Penetration-grade system and Performance-grade system) were conducted on the asphalt's properties in three different aging states (the original state, the short-term aging state, and the long-term aging state). The high temperature properties of asphalt improved, and the lower temperature properties of asphalt declined. The variation trends in the three different states were also expressed by using the linear regression. The durability of the asphalt was evaluated based on these aged trends. It was evident that the durability of asphalt binder was related not only to the additive content but also to the asphalt binder type and aging state.

Key words: *Aging state; Long-term properties; Penetration-grade system; Performance-grade system; Sasobit modified asphalt.*

Introduction

Warm Mix Asphalt (WMA) is the generic term for a variety of technologies that allow the producers of Hot Mix Asphalt (HMA) pavement material to lower the temperatures at which the material is mixed and placed on the road. The working temperature of WMA can be reduced 30-50°C compared to that of HMA. WMA can lend some obvious benefits: saving energy, reducing toxic emissions, decreasing fuel costs and asphalt aging, extending paving season, and enhancing the ability to haul paving mix for longer distances.

The development of WMA began in Europe with the German Bitumen Forum in 1997. At that time, the Kyoto agreement on green house gas reduction was in the process of being adopted by countries in the European Union. Since then, a number of products and processes for HMA temperature reduction have been developed in both Europe and the United States.

There are eight different types of WMA technologies: Synthetic Zeolite, Sasobit®, Evotherm®, WAM-Foam®, Double Barrel Green®, REVIXTM, Rediset TM WMX, and Low Energy Asphalt (LEA®). Sasobit is one of the eight different WMA technologies. It's often used as asphalt or an asphalt mixture additive [1, 2]. Sasobit is acquired from the coal gasification through the Fischer-Tropsch (FT) method. Therefore, it is also known as FT Paraffin Wax. It is a narrow distributed, long chain aliphatic hydrocarbon, and there are 40 to 115 carbon atoms in the main chain molecules. Sasobit shows the appearance of flake or powder, and its melting point is greater than 100°C, higher than ordinary paraffin [3, 4]. When Sasobit is added to asphalt at a temperature below its melting point, Sasobit forms a lattice structure in asphalt and improves the asphalt's viscosity. However, when Sasobit is blended into the asphalt at a temperature higher than its melting point, Sasobit completely dissolves in asphalt and reduces the asphalt's viscosity. Thus, it can decrease the working temperature of asphalt mixture in 30°C -50℃.

In recent years, Sasobit has been used as a compaction aid and a temperature reducer. In 1997, Sasobit began to be marketed in Europe as an asphalt mixture compaction aid by Sasol Wax International AG (http://www.sasolwax.com/Applications.html). From then on, over 142 projects throughout the world have been paved using Sasobit [1]. Projects were constructed in Austria, Belgium, China, Denmark, France, Germany, Italy, Switzerland, the United Kingdom, and the United States, etc. Since 2005 in China, Sasobit has been used in a variety of diverse pavement projects ranging from dense and open graded mixes to stone mastic asphalt.

In order to popularize the Sasobit technology, the bulk of work involving asphalt mixture containing Sasobit has been researched. By now, it can be accepted that Sasobit not only reduces the working temperature of asphalt mixture but also ensures the performance of asphalt mixture, which is equivalent with the HMA. However, there is little systematic research upon the durability of asphalt binder containing Sasobit.

Research Objective and Scope

In this study, two types of asphalt binders (Pen 60/80 asphalt and SBS modified asphalt) were designated as base asphalts. Then the asphalt binders containing Sasobit were named Sasobit modified asphalt. The additional content of Sasobit was 2%, 3%, 4% and 5% by mass of asphalt. The Sasobit modified asphalt, of which base asphalt was Pen 60/80 asphalt or SBS modified asphalt, was abbreviated to "PS" or "SS," respectively.

The main objective of this study is to characterize and evaluate the long-term properties of Sasobit modified asphalt through two sets of evaluating systems (Penetration-grade system and Performance-grade system). The Rolling Thin Film Oven (RTFO) and Pressure Aging Vessel (PAV) tests were used to simulate the short-term aging and the long-term aging of Sasobit modified asphalt. Moreover, the properties of Sasobit modified asphalt, such as viscosity, penetration, ductility, $G^*/\sin\delta$, $G^*.\sin\delta$ and S, were

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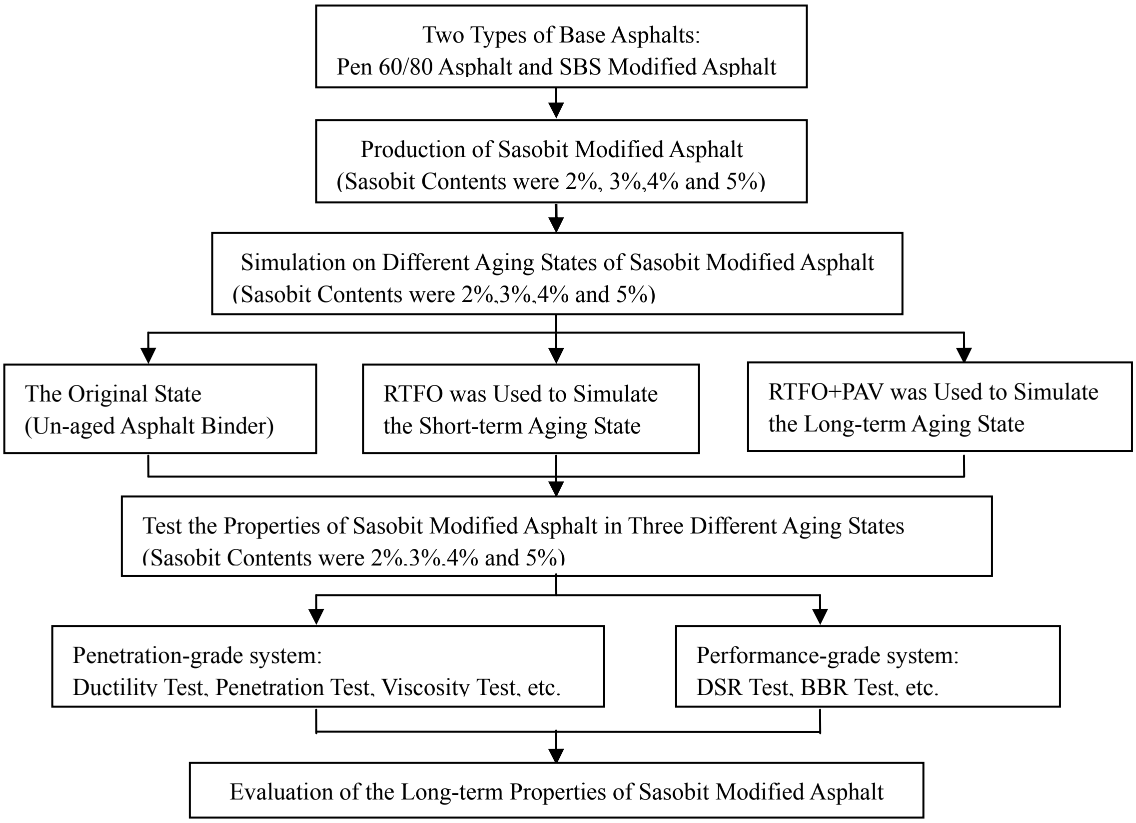


Fig. 1. Flow Chart of Experimental Design Procedures.

Table 1. Some Physical Properties of Sasobit.

Test Property	Melting Point(°C)	Flash Point(°C)	Viscosity (135°C, cp)	Viscosity (150°C, cp)	Penetration (25°C, 0.1 mm)	Penetration (60°C, 0.1 mm)
Result	100	290	5.47	3.26	1	8

Table 2. Some Properties of Two Base Asphalt Binders

Items	Penetration (25°C, 0.1 mm)	Softening Point(°C)	Viscosity (135°C, Pa.s)	Ductility (5°C, cm)	After RTOF Residue		
					Mass Loss (%)	Ratio of 25°C Residual Penetration (%)	5°C Residual Ductility (cm)
SBS Modified Asphalt	63	67.7	1.68	35.3	0.2	79.3	17.8
Pen 60/80 Asphalt	71	49.6	0.46	6	0.1	67.6	4.6

tested and evaluated in the original, short-term aging and long-term aging state. Fig. 1 shows a flow chart of the experimental design used in this study.

Properties of Raw Materials

Sasobit, Pen 60/80 asphalt, and SBS modified asphalt were used as additive and base asphalts in this study. Some of the physical properties of these raw materials are listed in Table 1 and Table 2.

Test Program

Production of Sasobit Modified Asphalt

The 3% PS (3% Sasobit by mass of the asphalt added into the Pen 60/80 asphalt) was used as the sample to determine the appropriate production procedures. Two production procedures were prepared for PS. One was the manual stirring method; the other was the mechanical shearing method. During each production procedure, the blending temperature was 130℃, 150℃, and 170℃ with times of 15 minutes, 30 minutes, and 45 minutes, respectively. The softening point margin of 3% PS was tested in accordance with *The Separation of Polymer Modified Asphalt Test* (ASTM D7173). This test is usually used to evaluate the storage stability of polymer modified asphalt. Samples of the asphalt are checked for stratification by *The Softening Point Test* (T0606-2000).

The Procedures of the Separation of Polymer Modified Asphalt Test includes the main following steps: First, pour the prepared 3% PS (50.0 g ± 0.1 g) into two tubes carefully, keep the tubes in a vertical position, seal the tubes and put them in the 163℃±5℃ oven for a period of 48±1hr. Secondly, at the end of the heating period, remove the tubes from the oven and immediately place them in the freezer at 0°C for at least a minimum of 4 hours. Finally, cut each tube into three equal segments. Place the top third and bottom third of each tube and mark them "top" and "bottom," respectively. The center third is discarded. Test the softening points of "top" and "bottom" asphalt samples separately and simultaneously, then calculate the softening point margin between "top" and "bottom" asphalt samples.

This test demonstrates that polymer modified asphalt will be in good hot storage condition when the softening point margin between top and bottom asphalt samples is within 3℃. Thus, this study used the test to judge the best production procedure for Sasobit modified asphalt. The best production procedure is used when the softening point margin of 3% PS is achieved with the smallest value.

According to the test results, the softening point margins of 3% PS satisfy the current specification in *Specification for Construction Highway Asphalt Pavements* (JTG F40-2004). All of the softening point margins of 3% PS were lower than the allowable value (3°C), which the specification prescribed. Predictably, the different production procedures have no negative effect on the hot storage stability of 3% PS, and the tendency for phase separation of 3% PS would not occur. Finally, this study has chosen the production procedure of Sasobit modified asphalt, which was blended for 30 minutes at 130°C by using the manual stirring method.

Asphalt Binder Test

The asphalt binder tests are conducted to quantify the asphalt's properties at three different states of its life: in its original state, after mixing and construction (short-term aging), and after in-service aging (long-term aging). The RTFO and RTFO+PAV procedures are used to artificially stimulate the mixing and construction aging state and in-service aging state. In this study, the base asphalt and Sasobit modified asphalt were then artificially aged through the RTFO and RTFO+PAV procedures.

The index of Penetration-grade system, such as 25°C penetration, softening point, and viscosity at different temperature of asphalts in three different aging states, were tested in accordance with the current test specification *Standard Test Method of Bitumen and Bituminous Mixture for Highway Engineering* (JTG 052-2000). In

Table 3. Properties of Sasobit Modified Asphalt in Three Different Aging States**.**

Items	Penetration (25℃,0.1 mm)	Softening point(℃)	Ductility (5°C or 15°C,cm)	Viscosity (135℃, Pa.s)	Viscosity (163℃, Pa.s)	Aging State
SBS Modified Asphalt	63	67.7	35.3	1.68	0.73	Original
SS(+2%Sasobit)	42	94.7	20.1	1.59	0.55	
SS(+3%Sasobit)	40	97.3	17.5	1.28	0.46	
SS(+4%Sasobit)	33	101.6	13.5	1.19	0.45	
SS(+5%Sasobit)	33	107.0	8.3	1.11	0.42	
SBS Modified Asphalt	50	70.5	17.8	2.21	0.65	Short-Term Aging
SS(+2%Sasobit)	32	97.9	12.3	2.13	0.57	
SS(+3%Sasobit)	29	101.6	6.2	1.93	0.48	
SS(+4%Sasobit)	27	102.8	4.6	1.79	0.47	
SS(+5%Sasobit)	25	111.5	1.8	2.20	0.42	
SBS Modified Asphalt	36	74.0	1.8	2.64	0.59	Long-Term Aging
SS(+2%Sasobit)	28	98.8	1.5	2.89	0.46	
SS(+3%Sasobit)	24	102.8	1.3	2.54	0.41	
SS(+4%Sasobit)	23	108.1	1.2	2.34	0.45	
SS(+5%Sasobit)	21	117.6	1.2	2.56	0.43	
Pen 60/80 Asphalt	71	49.6	124.0	0.46	0.09	Original
PS(+2%Sasobit)	61	66.3	53.1	0.40	0.08	
PS(+3%Sasobit)	50	79.9	42.3	0.32	0.07	
PS(+4%Sasobit)	46	88.5	36.3	0.39	0.06	
PS(+5%Sasobit)	41	92.8	28.1	0.35	0.05	
Pen 60/80 Asphalt	47	53.0	71.0	0.48	0.16	Short-Term Aging
PS(+2%Sasobit)	44	68.2	27.2	0.42	0.13	
PS(+3%Sasobit)	35	80.2	14.5	0.38	0.13	
PS(+4%Sasobit)	36	87.8	14.1	0.36	0.12	
PS(+5%Sasobit)	30	93.5	8.2	0.38	0.12	
Pen 60/80 Asphalt	34	59.3	9.0	0.74	0.20	Long-Term Aging
PS(+2%Sasobit)	30	73.0	7.6	0.60	0.18	
PS(+3%Sasobit)	29	83.0	7.0	0.53	0.16	
PS(+4%Sasobit)	28	90.7	3.4	0.62	0.18	
PS(+5%Sasobit)	30	92.8	4.1	0.47	0.14	

Note: According to *the Standard Test Method of Bitumen and Bituminous Mixture for Highway Engineering* (JTG 052-2000), the test temperature of ductility for SBS modified asphalt, and the Pen 60/80 asphalt are 5°C and 15°C, respectively.

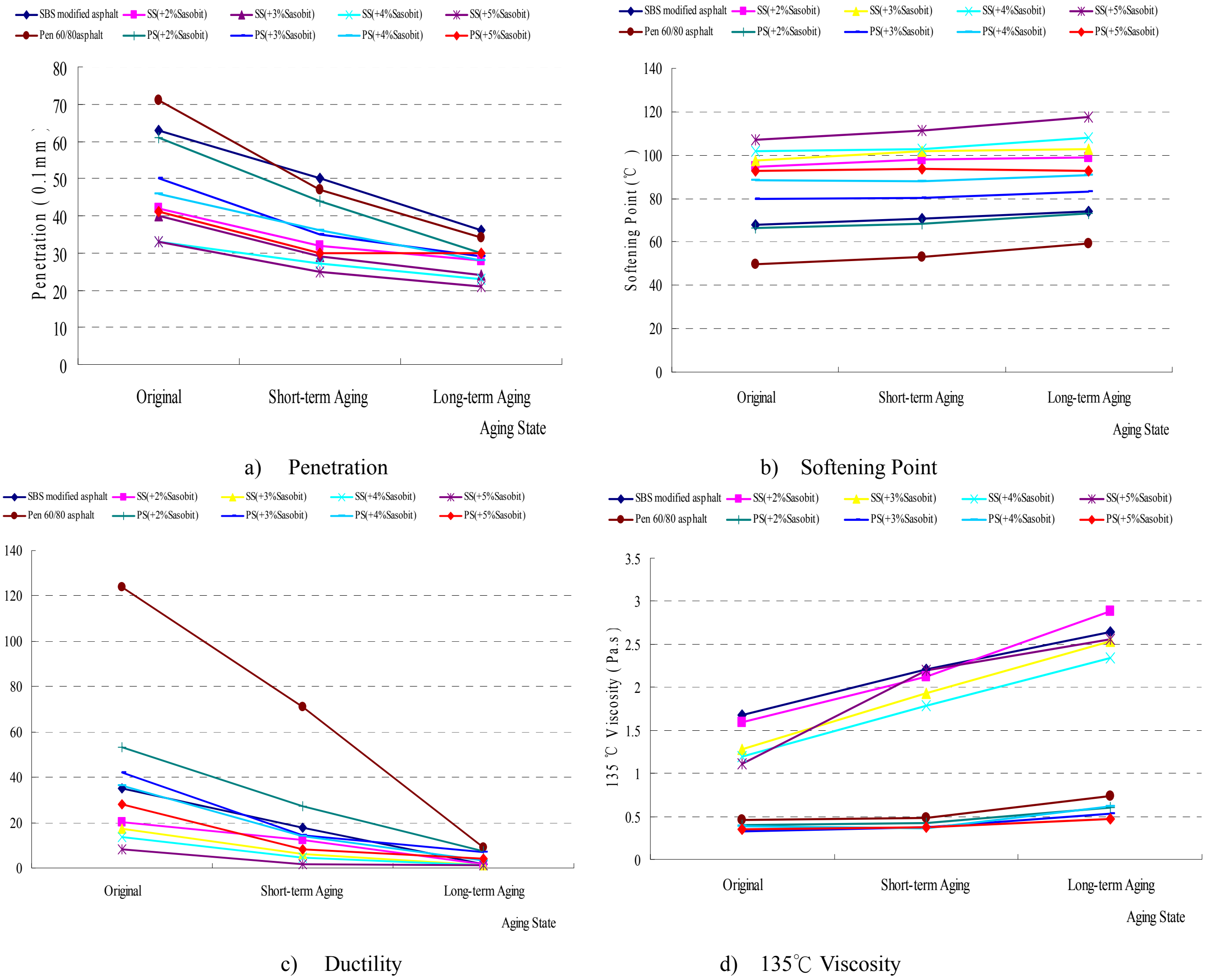


Fig. 2. Properties of Sasobit Modified Asphalt Varies with Aging States.

this study, the tests include *The Penetration Test* (T0604-2000), *The Ring-and-Ball Softening Point Test* (T0606-2000), *The Ductility Test* (T0605-1993) and *The Viscosity Test* (T0625-2000).

The index of the Performance-grade system, such as $G^*/\sin\delta$, $G^*.\sin\delta$, S and m Value, of asphalts in three different aging states were tested in accordance with *The Dynamic Shear Rheometer Test* (ASTM TP5) and *The Bending Beam Rheometer Test* (ASTM TP1).

Results and Discussions

Properties of Sasobit Modified Asphalt Under the Penetration-grade System

The properties of Sasobit modified asphalt in three different aging states, as determined by using the Penetration-grade system, are summarized in Table 3 and Fig. 2.

As shown in Table 3, regardless of the PS and SS aged state, the 25°C penetration, 135°C viscosity, 163°C viscosity, and ductility reduced with the increase of Sasobit content, but the softening point increased with the Sasobit content. This means that Sasobit can change and set a similar variation effect on the properties of PS and SS. In other words, the high temperature properties of PS and SS were upgraded while the lower temperature properties of PS and SS were decreased. In order to avoid the lower temperature properties of PS and SS to decline sharply, the appropriate Sasobit content needs to be met. In this study, the optimum Sasobit content was 3%.

The variation ratios of properties, such as ascent ratio of high temperature properties and descent ratio of lower temperature properties, for PS and SS varied in three different aging states in Table 4. The aged speed became faster and faster when the aged state became deeper and deeper

In Fig. 2, the three different aging states and the different indices of Sasobit modified asphalt were demonstrated along the X-axis and Y-axis, respectively. It can be observed that the softening point and viscosity of PS and SS increased, and the 25°C penetration and ductility of PS and SS declined as the aged speed increased. This means that the properties of PS and SS became worse and worse, and their anti-aging capacities were reduced as the aging degree deepened. However, the variation trends, which happened between the anti-aging capacities of PS and SS and the aging state, can be expressed with linear regression. The correlation coefficients of all linear regressions were beyond 0.9.

Compared to the variation trends of PS or SS in the same aging state, the variance ratios of SS were obviously slower than those of PS. This means that the anti-aging capacities or durability of SS were better than those of PS. Thus this study predicts that, besides Sasobit content itself, the base asphalt type is a very important factor in affecting the properties and durability of Sasobit modified asphalt. In spite of the fact that the variance ratios of PS and SS were different, their overall variation trends were similar.

Properties of Sasobit Modified Asphalt under the Performance-grade System

DSR of Sasobit Modified Asphalt in Three Aging States

The DSR test results of Sasobit modified asphalt in the different aging states are labeled in Tables 4-6 and Fig. 3. In Tables 4-6, the G*/sinδ of SS and PS in the original state and short-term aging state increased with the increase of Sasobit content in the same temperature. While the Sasobit content was 3%, the G*/sinδ of SS and PS achieved maximum value. This means that the high temperature properties of SS and PS upgraded, and the Sasobit content had a strong influence on the properties of SS and PS. In this study, the optimum Sasobit content was 3%. This recommended value is consistent with the one suggested by using the Penetration-grade system.

Obviously, the G^*/sinδ ascent ratio of SS was slower than that of PS. The high temperature grade of PS improved at least one degree, but the high temperature grade of SS did not change. The results predict that the base asphalt type was the important factor in determining the properties of Sasobit modified asphalt compared to the Sasobit content. It is seen that in a long-term aging state, the G*.sinδ of SS and PS increase with the increase of Sasobit content in the same temperature. The rising value of G*.sinδ means that the anti-fatigue capacity of asphalt became lower. Obviously, the G*.sinδ ascent rate of SS was slower than that of PS. It is also

Table 4-1. DSR of SS in Original State.

Items	G^* (kPa)				δ(°)				G^*/sinδ (kPa)			
	64°C	70°C	76°C	82°C	64°C	70°C	76°C	82°C	64°C	70°C	76°C	82°C
SBS Modified Asphalt	4.44	2.49	1.47	0.95	63.61	63.82	63.07	60.13	4.96	2.77	1.65	1.09
SS(+2%Sasobit)	7.02	4.10	2.51	1.61	58.99	57.65	56.14	54.10	8.19	4.85	3.02	1.98
SS(+3%Sasobit)	9.41	5.58	3.47	2.14	51.86	49.96	48.30	49.97	11.98	7.29	4.65	2.79
SS(+4%Sasobit)	9.32	5.46	3.36	2.26	54.29	52.87	51.63	46.25	11.48	6.86	4.29	2.13
SS(+5%Sasobit)	8.07	4.57	2.67	1.67	58.48	57.12	55.71	54.14	9.47	5.45	3.24	2.06

Table 4-2. DSR of SS in Short-term Aging State.

Items	G* (kPa)				δ(°)				G*/sinδ (kPa)			
	58°C	64°C	70°C	76°C	58°C	64°C	70°C	76°C	58°C	64°C	70°C	76°C
SBS Modified Asphalt	11.01	5.92	3.35	1.99	61.9	62.12	62.44	62.41	12.48	6.70	3.78	2.25
SS(+2%Sasobit)	13.47	7.31	4.22	2.53	61.16	60.32	59.53	58.43	15.37	8.42	4.89	2.97
SS(+3%Sasobit)	17.69	9.35	5.13	3.01	60.77	60.03	59.35	58.42	20.26	10.8	5.96	3.53
SS(+4%Sasobit)	13.07	6.83	3.65	2.03	64.09	64.36	64.94	65.48	14.53	7.58	4.03	2.23
SS(+5%Sasobit)	18.29	9.53	5.05	2.58	61.75	61.78	62.15	63.14	20.76	10.82	5.71	2.90

Table 5-1. DSR of PS in Original State.

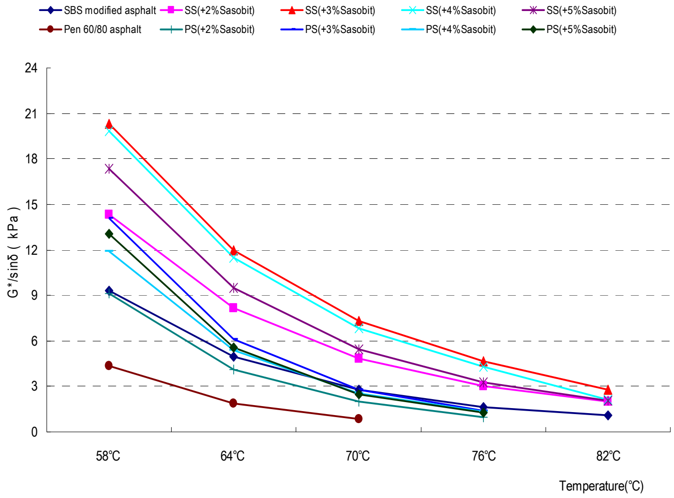
Items	G* (kPa)				δ(°)				G*/sinδ (kPa)			
	58°C	64°C	70°C	76°C	58°C	64°C	70°C	76°C	58°C	64°C	70°C	76°C
Pen 60/80 Asphalt	4.37	1.85	0.83	/	85.98	86.98	87.09	/	4.38	1.86	0.84	/
PS(+2%Sasobit)	8.95	4.05	1.95	0.98	79.77	80.61	81.31	81.46	9.10	4.11	1.98	1.00
PS(+3%Sasobit)	13.77	5.99	2.77	1.38	77.82	79.08	80.08	80.21	14.09	6.10	2.81	1.40
PS(+4%Sasobit)	11.64	5.28	2.53	1.28	78.56	79.41	80.04	79.95	11.88	5.37	2.56	1.30
PS(+5%Sasobit)	12.84	5.48	2.46	1.23	79.68	81.43	82.85	83.26	13.05	5.54	2.48	1.24

Table 5-2. DSR of PS in Short-term Aging State.

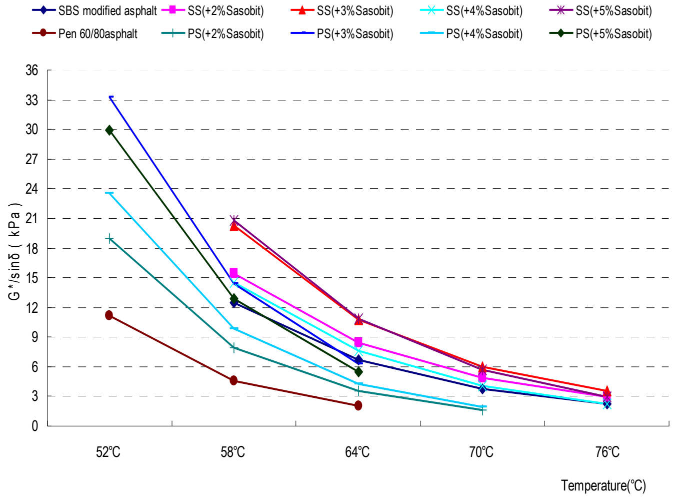
Items	G* (kPa)				δ(°)				G*/sinδ (kPa)			
	52°C	58°C	64°C	70°C	52°C	58°C	64°C	70°C	52°C	58°C	64°C	70°C
Pen 60/80 Asphalt	11.1	4.57	1.98	/	83.17	85.2	86.63	/	11.18	4.58	1.98	/
PS(+2%Sasobit)	18.63	7.84	3.48	1.6	79.41	81.27	82.58	83.24	18.95	7.93	3.51	1.67
PS(+3%Sasobit)	32.29	14.11	6.16	/	76.2	77.64	78.9	/	33.25	14.45	6.28	/
PS(+4%Sasobit)	23.08	9.70	4.22	1.9	78.92	80.97	82.7	83.97	23.52	9.82	4.26	1.96
PS(+5%Sasobit)	29.04	12.58	5.42	/	75.81	77.64	79.47	/	29.96	12.87	5.51	/

Table 6. DSR of Sasobit Modified Asphalt in Long-term Aging State.

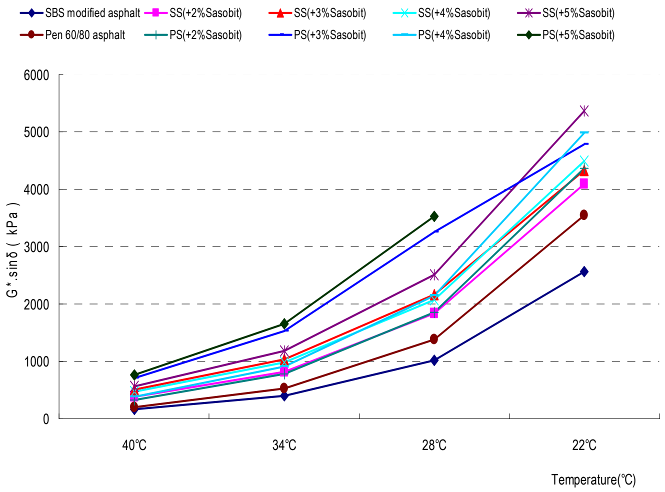
Items	G* (kPa)				δ(°)				G*.sinδ (kPa)			
	40°C	34°C	28°C	22°C	40°C	34°C	28°C	22°C	40°C	34°C	28°C	22°C
SBS Modified Asphalt	193.3	466.1	1271	3236	62.38	60.69	57.41	52.35	171.3	406.4	1025	2562
SS(+2%Sasobit)	451.4	1022	2381	5727	56.24	54.04	50.57	45.5	375.3	827.0	1839	4085
SS(+3%Sasobit)	630.1	1345	2900	6266	52.67	50.95	48.02	43.61	501.0	1044	2156	4322
SS(+4%Sasobit)	607.9	1270	2786	6443	51.94	50.62	48.25	44.15	478.7	981.4	2079	4488
SS(+5%Sasobit)	701.5	1493	3310	7678	53.56	52.16	49.34	44.24	564.4	1179	2511	5357
Pen 60/80 Asphalt	219	583	1612	4486	69.53	64.71	58.98	52.12	205.7	527.2	1382	3541
PS(+2%Sasobit)	357	892	2247	5824	65.72	60.9	55.33	48.43	325.7	780.0	1848	4357
PS(+3%Sasobit)	842	1912	4328	10010	57.65	53.36	48.59	42.62	711.9	1534	3246	4775
PS(+4%Sasobit)	427	1059	2645	6737	64.35	59.8	54.34	47.66	384.9	915.5	2152	4979
PS(+5%Sasobit)	903	2043	4657	/	57.52	53.84	49.17	/	761.8	1649	3524	/



a) G*/sinδ of Sasobit Modified Asphalt in Original State



b) G*/sinδ of Sasobit Modified Asphalt in Short-term Aging State



c) G*.sinδ of Sasobit Modified Asphalt in Long-term Aging State

Fig. 3. G*/sinδ and G*.sinδ of Sasobit Modified Asphalt in Three Different Aging States.

evident that the base asphalt type affects the properties of Sasobit modified asphalt critically.

BBR of Sasobit Modified Asphalt in Three Aging States

The BBR test results of Sasobit modified asphalt in the different aging states are listed in Table 7 and Fig. 4.

In Table 7, the S of SS and PS increased with the increase of Sasobit content in the same temperature with the three different aging states. While the Sasobit content was higher than 3%, the

Table 7. S and m of Sasobit Modified Asphalt in Three Different Aging States.

Items	S (MPa)			m Value			Aging State
	-12°C	-18°C	-24°C	-12°C	-18°C	-24°C	
SBS modified asphalt	88.7	232.2	487.9	0.460	0.421	0.404	Original
SS(+2%Sasobit)	116.9	225.6	981.1	0.391	0.396	0.297	
SS(+3%Sasobit)	126.4	226.5	663.8	0.377	0.368	0.372	
SS(+4%Sasobit)	133.9	365.7	795.0	0.348	0.354	0.395	
SS(+5%Sasobit)	161.9	384.9	1394.6	0.334	0.336	0.425	
SBS modified asphalt	94.3	231.3	619.7	0.429	0.391	0.411	Short-Term Aging
SS(+2%Sasobit)	136.0	223.8	1011.6	0.319	0.396	0.302	
SS(+3%Sasobit)	133.4	270.1	1276.1	0.389	0.324	0.441	
SS(+4%Sasobit)	148.7	339.0	1169.1	0.333	0.351	0.42	
SS(+5%Sasobit)	162.4	387.7	1438.2	0.348	0.360	0.328	
SBS modified asphalt	84.3	247.6	954.7	0.394	0.426	0.413	Long-Term Aging
SS(+2%Sasobit)	130.4	291.8	1382.2	0.345	0.365	0.376	
SS(+3%Sasobit)	191.1	413.8	845.9	0.355	0.345	0.383	
SS(+4%Sasobit)	151.4	328.2	824.09	0.353	0.382	0.406	
SS(+5%Sasobit)	195.9	375.2	725.8	0.349	0.355	0.371	
Pen 60/80 asphalt	111.4	231.5	445.7	0.431	0.441	0.417	Original
PS(+2%Sasobit)	105.2	235.8	640.4	0.387	0.391	0.409	
PS(+3%Sasobit)	171.5	281.7	724.2	0.394	0.416	0.388	
PS(+4%Sasobit)	142.2	282.4	539.1	0.367	0.385	0.352	
PS(+5%Sasobit)	144.5	265.2	997.6	0.377	0.358	0.318	
Pen 60/80 asphalt	117.5	329.7	585.9	0.461	0.443	0.455	Short-Term Aging
PS(+2%Sasobit)	111.3	376.2	801.3	0.409	0.415	0.467	
PS(+3%Sasobit)	179.3	391.1	925.0	0.427	0.403	0.480	
PS(+4%Sasobit)	149.3	412.9	840.0	0.407	0.389	0.430	
PS(+5%Sasobit)	152.6	361.7	797.7	0.378	0.401	0.356	
Pen 60/80 asphalt	146	465.7	986.4	0.406	0.402	0.437	Long-Term Aging
PS(+2%Sasobit)	176.2	456.1	1128.4	0.386	0.382	0.448	
PS(+3%Sasobit)	170.7	336.6	1778.9	0.423	0.391	0.356	
PS(+4%Sasobit)	191	533.3	1440.8	0.355	0.378	0.506	
PS(+5%Sasobit)	196.6	497.1	1035.3	0.346	0.376	0.404	

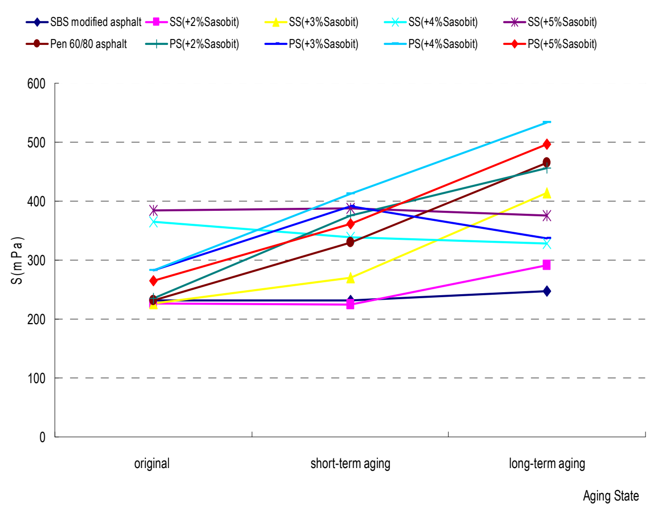


Fig. 4. S of Sasobit Modified Asphalt under -18°C in Three Different Aging States.

lower temperature of SS degraded a degree. The lower temperature properties of Sasobit modified asphalt became worse with the increase of Sasobit. This means that the Sasobit had a negative effect on the lower temperature properties of Sasobit modified asphalt. The results have been confirmed by using the Penetration-grade system. In this study, the upper limit of Sasobit content was 3%.

As shown in Fig. 4, the anti-cracking capacity or durability of SS and PS reduced as the aging degree deepened. Nearly all of S for PS and SS met with the technical requirement (max, 300 mPa) in the original state, except for SS (+4% Sasobit) and SS (+5%Sasobit). However, whether the aging degree was short-term aging or long-term aging, almost all of S for PS and SS did not satisfy the technical requirement. The lower temperature properties of PS and SS failed when the aging state strengthened.

Conclusions

This study investigates the long-term properties of Sasobit modified asphalt. From the above mentioned results, the following conclusions were drawn for the materials used in this study:

1. Sasobit is used as an additive. It can change the properties of asphalt after adding Sasobit into the base asphalt. Overall, the

high temperature properties of Sasobit modified asphalt improve and the lower-temperature properties of Sasobit modified asphalt reduce. These results have been proven by using the Penetration-grade system and Performance-grade system. The properties of Sasobit modified asphalt are affected not only by the base asphalt type but also by the Sasobit content. Relatively, the variation ranges of properties for SS are slower than those of PS, so it can be predicted that the base asphalt type is a more important factor than the Sasobit content.

2. The Sasobit content affect the properties of Sasobit modified asphalt. While the Sasobit content is higher than 3%, the lower temperature properties of Sasobit modified asphalt degrade a degree, and the anti-cracking capacity can decline sharply. It is also found that the high temperature properties of Sasobit modified asphalt have a direct relationship to the Sasobit content. When the Sasobit content is 3%, $G^*/\sin\delta$ reaches the maximum. Thus the optimum Sasobit content is suggested, and the 3% Sasobit content is suggested in this study. The aging of Sasobit modified asphalt appeared the different aged characters in the different aging state. In general, the durability, such as anti-aging capacity, anti-cracking capacity and anti-fatigue capacity, of Sasobit modified asphalt declines with the acceleration of the aging state. This means that the durability in the long-term aging state is followed by the durability in the short-term aging state and so on. In this study, the aging trends of Sasobit modified asphalt followed by the aging state are very similar and can be expressed by using linear regression.

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