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Studying the modification of asphalt binder by using sasobit additive

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Abstract

Warm mix asphalt (WMA) binders with varying amounts of Sasobit additive are made using two kinds of asphalt binders (PEN80-100 and 60-70). The Sasobit content was from 0.4% to 2.0%, with a range of 0.4 by mass of asphalt binder. Penetration, Rotational Viscosity (RV), and Dynamic Shear Rheometer (DSR) tests were performed. In addition, the Rolling Thin Film Oven (RTFO) and the Pressure Aging Vessel (PAV) tests were carried out to simulate the short-term and long-term aging of asphalt binder, respectively. Furthermore, for both asphalt binders, the complex shear modulus (G*) was determined in order to calculate the rutting factor (G*/Sinδ) and fatigue factor (G*. Sinδ). The results obtained reveal that, the asphalt performs better at higher temperatures and worse at lower ones. Because excessive amounts of Sasobit will negatively affect the asphalt binder, it should be added to the asphalt binder at a mass percentage of no more than 2%.

Keywords: *Asphalt binders, Dynamic Shear Rheometer, Fatigue factor,* Rolling Thin Film Oven, *Warm mix asphalt.*

1. Introduction

WMA is a more environmentally friendly and efficient option, compared with, hot mix asphalt (HMA), because it can be mixed and compacted at lower temperatures [1-2]. WMA can be created in three ways: Emulsified asphalt, foamed asphalt, and organic additives, such aspha-min and Sasobit, are all viable options [3]. The majority of WMA research has been on validating road performance, determining additive dose, and developing construction methods. Zhang et al. [4] made models of Evotherm warm mix asphalt (E-WMA) with the same size of aggregates, examined the performance of these E-WMAs and HMA, and compared the results. The mix was made by Xu [5], who used a specially made SBS emulsion as the hot mixture's binder. The road's performance was measured and compared with that using SBS HMA. Li [6] and Zhang [7] performed a series of in-house experiments, using Sasobit warm mix asphalt (S-WMA). By applying the Marshall test, the rutting test, the low-temperature bend test, and the water stability test to evaluate HMA and S-WMA as roads, Ji [8] developed the viscosity-temperature curve. The effects of viscosity on the mixing and compacting temperatures of WMA were investigated by Zhou [9]. Viscosity investigations were employed by Wu [10, 11] to establish the optimal mixing and compacting temperatures for WMA. The findings showed that, mixing and compacting at temperatures 10 to 20 °C lower than those used for warm-mixed asphalt mixtures can greatly improve the mixture's high-temperature stability. Warm-mixed asphalt mixture retains strong low-temperature fracture resistance, fatigue resistance, and water stability, although the mixing process alters these qualities. Regardless, it has beneficial properties and is safe for the planet. In general, S-WMA is reported to have superior high-temperature stability, compared to other materials, excellent workability, energy saving, and environmental protection properties, and is extensively used [12-13]. The effects of Sasobit on ageing at various ages were examined. To model short and long-term aging, the RTFO and PAV tests were employed, respectively. Meanwhile, Penetration tests, rotating viscosity tests (RV), and dynamic shear rheometers (DSR) were carried out to measure the physical and rheological characteristics of virgin and modified asphalt binders.

2. Materials and methods of experiment

2.1. Materials and samples preparation

As the basis material, two kinds of asphalt with penetration of 60-70 and 80-100 were used. Table 1 lists the matrix asphalt binders' properties. Sasol Wax is the South African manufacturer of Sasobit. The process of gasifying coal results in the production of this long-chained aliphatic hydrocarbon. Its melting point is about 99°C; if it is stirred above 110°C, it would melt evenly in asphalt [14]. It has been demonstrated that, S-WMA technology is superior. In this research, it was employed as an additive at concentrations of 0.4%, 0.8%, 1.2%, 1.6%, and 2.0% by weight of asphalt.

Table 1: The properties of asphalt binders

Kind of asphalt	Penetration at 25°C/0.1 mm	Softening Point (°C)	Ductility at 15°C/cm
60-70	65	50	110
80-100	81	48	120

2.2. Experimental methods

The penetration test is a traditional standard for evaluating asphalt binders. ASTM D-5 penetration test was run at 25°C to evaluate the binders' stability [15]. The rheological behavior of materials was investigated using the ASTM D-4402 rotating viscosity (RV) test at temperatures of 105, 135, and 165°C [16].
As outlined by ASTM D2872 [17], the RTFO test is employed to simulate the short-term aging of asphalt. The PAV test (ASTM D6521) is designed to model how asphalt binders age over a long period, usually 7 to 10 years. Since there is no definitive pass/fail standard for the PAV test, the asphalt binder must be aged before being evaluated.
To evaluate the viscoelastic behaviour of intricate materials, such as asphalt binders, a dynamic shear rheometer (ASTM D7175) can be utilized [18]. There are three stages of testing for the DSR:

- Fresh asphalt binder: High temperatures are applied to the asphalt binder (between 46 and 76°C, rising by 6°C at a time).
- Asphalt binder with RTFO aging: The asphalt binder is heated between 46 and 82°C in 6-degree increments.
- Asphalt with PAV aging: This test examines the asphalt binder's performance between 22 and 40°C in 6-degree increments.

3. Data analysis and results

3.1. The results of the penetration test

Figure 1 and Figure 2 show the original and short-term aged asphalt binder 80-100 and 60-70 penetration values, respectively. Penetration test was done for both types of asphalt binders at 25°C. According to these figures, the penetration value of both types of asphalt binders decreased after modification, and the lowest penetration value is at 2.0% Sasobit modified original asphalt binder. This indicates that, Sasobit can decrease the penetration value. Furthermore, Sasobit had the same effect in short-term aged asphalt binders. Besides, based on these findings, penetration values decreased for both types of asphalt, after aging.

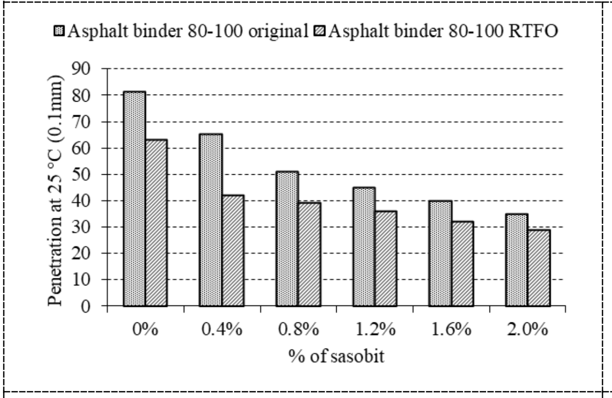


Fig. 1: The Penetration values of asphalt binder 80-100 at various Sasobit rates.

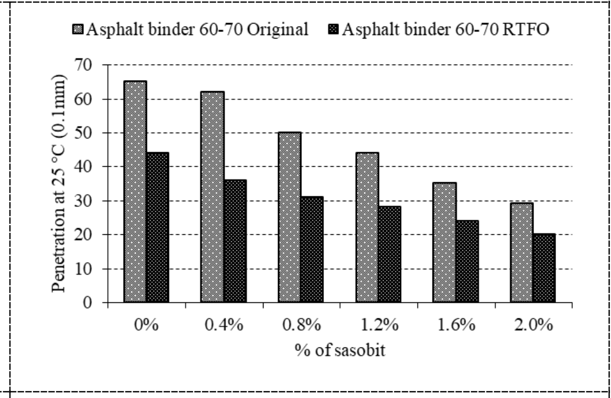
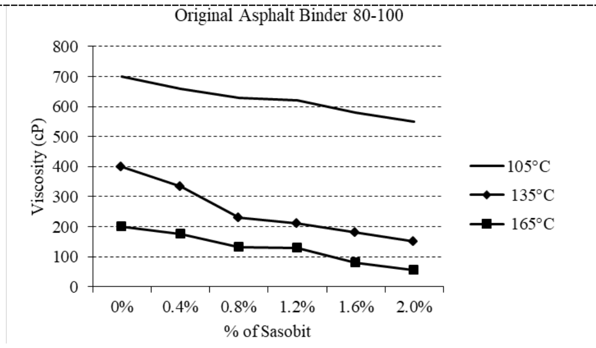


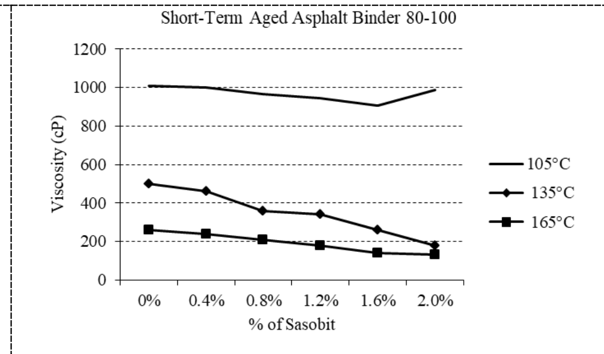
Fig. 2: Penetration values of asphalt binder 60-70 at different Sasobit rates.

3.2 The results of viscosity test

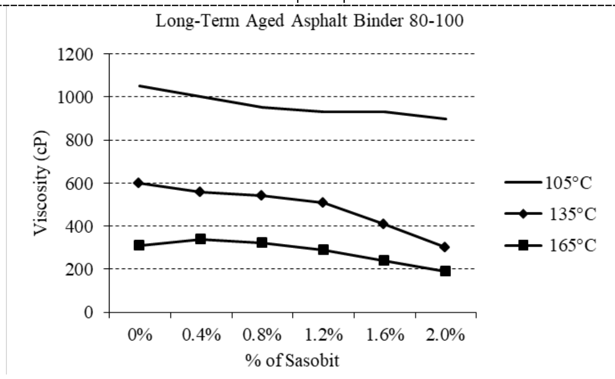
The asphalt's fluidity, as well as its mixture and agitating abilities, are directly proportional to the asphalt binder's viscosity [19]. The asphalt binder's viscosity varies with temperature, where it reduces as the temperature rises. Furthermore, the higher the Sasobit dose, the lower the viscosity of the binder. Asphalt with lower viscosity is less difficult to mix and compact and requires less temperature. Viscosity tests were done for asphalt binders PEN80-100 and PEN60-70 at temperatures 105°C, 135°C (mixing temperature), and 165°C (laying temperature). Figures 3 and 4 compare unaged, short-term, and long-term aged Sasobit modified asphalt binders 80-100 and 60-70 at different temperatures. Figures 3 and 4 illustrate how Sasobit decreased the viscosity of asphalt binders PEN80-100 and PEN60-70 at all three considered temperatures of 105°C, 135°C, and 165°C. According to the data, binders become less viscous as the temperature rises. In addition, the viscosity of asphalt binders rose after aging, according to these graphs.



a) Sasobit's effect on the original asphalt binder 80-100.

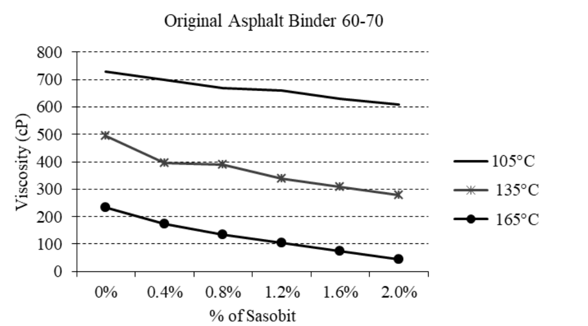


b) Sasobit's effect on RTFO asphalt binder 80-100.

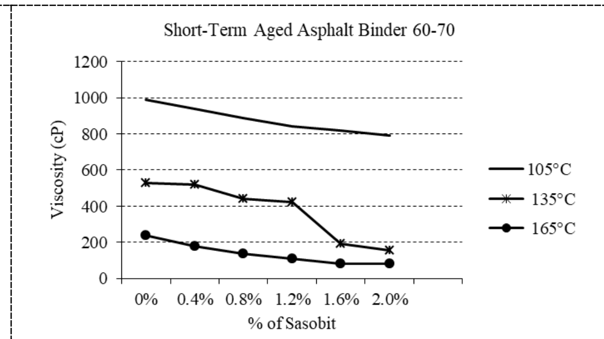


c) Sasobit's effect on PAV asphalt binder 80-100.

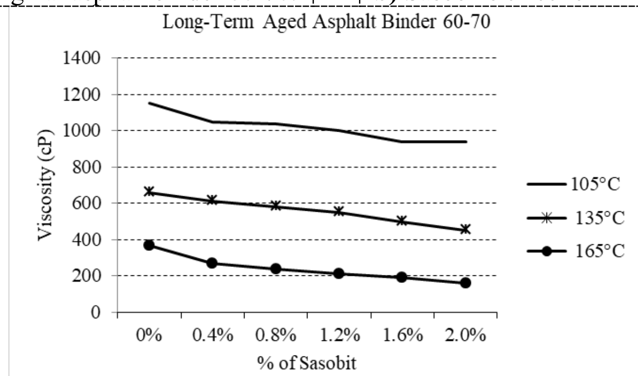
Fig. 3: Sasobit contents' effect on the viscosity of asphalt binder 80-100 at various aging stages.



a) Sasobit's effect on the original asphalt binder 60-70.



b) Sasobit's effect on RTFO asphalt binder 60-70.



c) Sasobit's effect on PAV asphalt binder 60-70.

Fig. 4: Sasobit contents' effect on the viscosity of asphalt binder 60-70 during various aging stages.

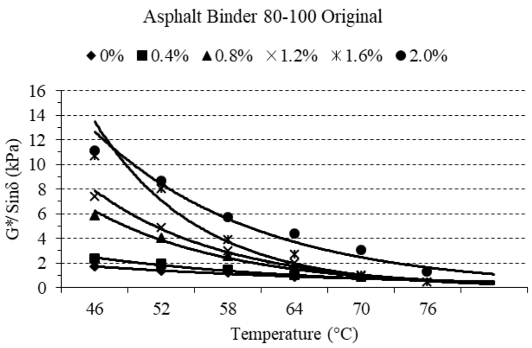
3.3 DSR results

3.3.1. Rutting parameter (G*/sinδ)

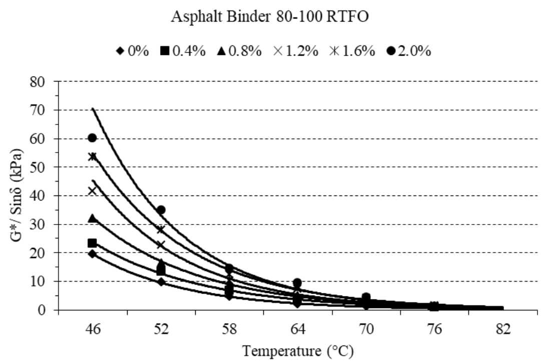
When a large number of vehicles drive over the pavement, rutting will begin to form. In order to prevent rutting failures, asphalt has to be both strong enough to withstand the stresses applied to it and elastic enough to spring back to its original form, after being deformed [19]. The following equation (1) describes the dissipated work (Wc) after each loading cycle.

$$W_C = \pi\sigma^2 (1/[G*/\sin\delta]) \quad (1)$$

PAV-aged asphalt binder's rutting parameter is unrestricted, since rutting only happens in the pavement's early stages. The rutting parameter is shown against the test temperature in Figures 5 and 6, respectively, for the fresh binders PEN80-100 and PEN60-70 and RTFO aging, with different concentrations of Sasobit. The G*/sinδ value for both the original and RTFO binders decreased exponentially as the test temperature increased. Lower temperatures showed a faster decline in G*/sinδ value, while higher temperatures exhibited a slower decrease in G*/sinδ value. For fresh or RTFO binders, the rutting parameter increased linearly in line with an increase in Sasobit percentage. Resistance of the asphalt against rutting failure was significantly enhanced by Sasobit.

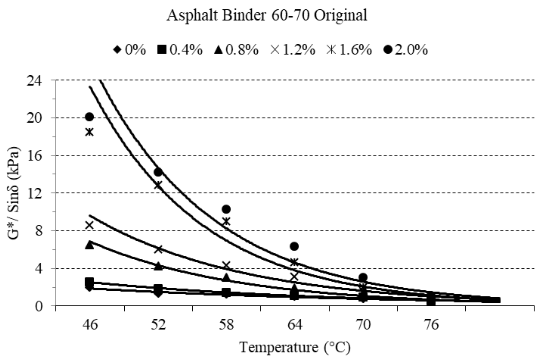


a) The original asphalt binder with G*/Sinδ of PEN80-100.

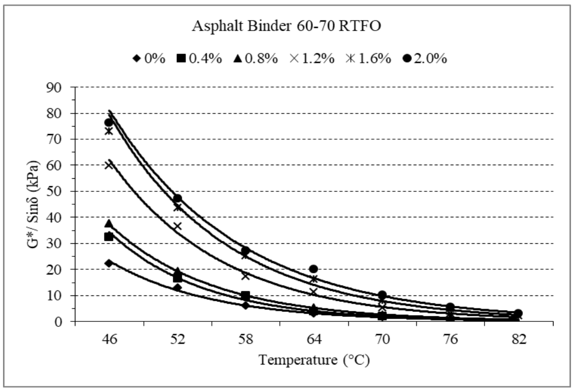


b) Asphalt binder with G*/Sinδ of 80-100 RTFO.

Fig. 5: Rutting parameter versus temperature of PEN80-100 asphalt binder.



a) The original asphalt binder with a G*/Sinδ of PEN60–70.



b) Asphalt binder with G*/Sinδ of 60-70 RTFO.

Fig. 6: Asphalt binder with G*/Sinδ of PEN60-70.

3.3.2. Fatigue parameter (G* sinδ)

After years of use and repeated stress from vehicles, asphalt pavements begin to crack due to fatigue. The asphalt binder must be flexible enough to spring back into its original shape without cracking [19]. Asphalt pavements with an adequate thickness can prevent fatigue cracking, a kind of strain. The following equation (2) describes the dissipated work (Wc) for the controlled strain test after each loading cycle.

$$W_C = \pi\varepsilon^2 (G * \sin\delta) \quad (2)$$

As a result, the Superpave specification limits G* sinδ for PAV-aged asphalt binder to a maximum of 5,000 kPa. For different Sasobit percentages in PEN80-100 and PEN60-70 asphalt binders, the fatigue parameter vs. test temperature is displayed in figures 7(a) and 8(a), respectively. With increasing test temperatures, the G* sinδ value decreased exponentially.

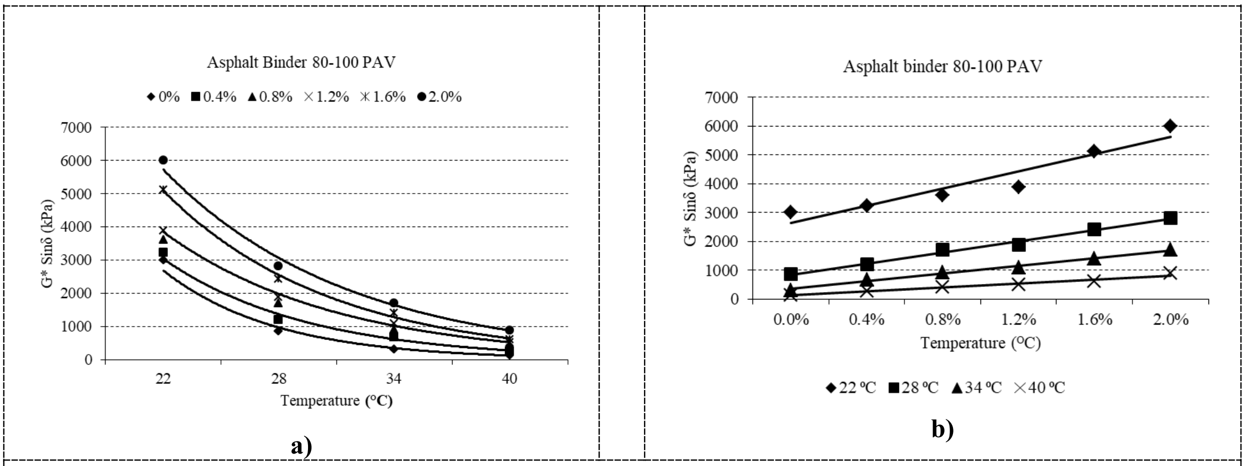


Fig. 7: The G* sinδ values of 80-100 PAV binder vs. (a) temperature and (b) % of Sasobit.

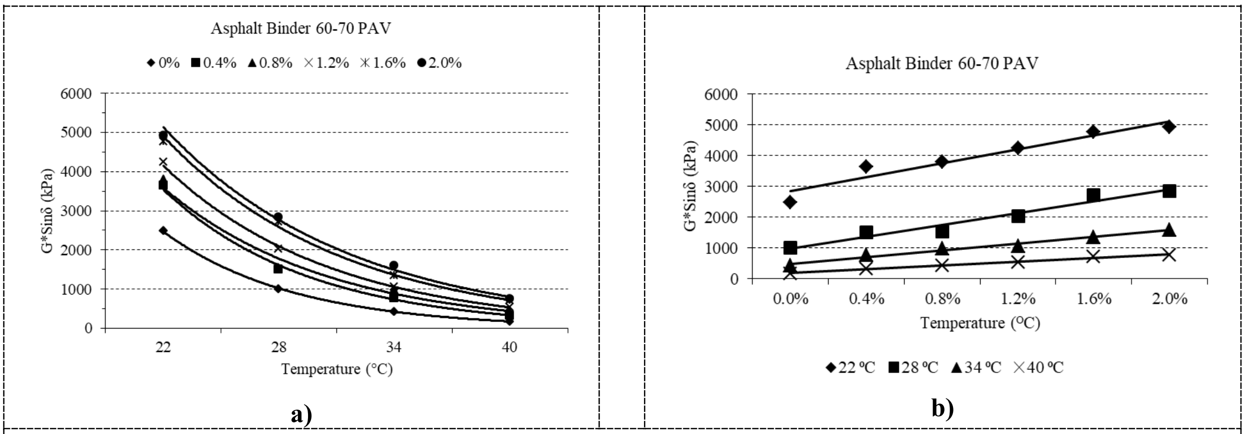


Fig. 8: The G* sinδ values of 60-70 PAV binder vs. (a) temperature and (b) % of Sasobit.

Figures 7(b) and 8(b) which exhibit the G* sin δ vs. the % of Sasobit at different test temperatures for asphalt binders 80-100PEN and 60-70PEN, respectively, indicate that, the fatigue parameter increased linearly as the percentage of Sasobit increased. After adding Sasobit proportions to asphalt binders, it was discovered that their performance against fatigue cracking decreased. Additionally, the value of G* sinδ was found to be less than the limits of the Superpave fatigue limit. Besides, cracks are not expected in all used asphalt kinds.

4. Conclusions

In comparison to traditional binders, Sasobit enhanced the physical and rheological properties of binders 80-100 and 60-70. Both the penetration value and the viscosity of the asphalt were reduced by the addition of Sasobit. And when compared to unmodified binders, the addition of Sasobit (0.4-2.0%) to the binder reduces viscosity. As was previously noted, the penetration value of aged asphalt decreased, while the viscosity of both asphalts increased after aging. Fresh and RTFO-aged binders, modified with Sasobit, perform better than unmodified binders at high temperatures, against rutting failures. Sasobitenhanced asphalt binders have a lower phase angle, greater complex modulus, and are stiffer. As the G* Sinδ (fatigue factor) increased, the anti-fatigue ability of asphalt binders decreased. Finally, to maximise the asphalt's resistance to thermal cracking, Sasobit should be added to the binder at a rate of 2.0%.

References

[1] Kheradmand, Behnam et al 2014 An Overview of the Emerging Warm Mix Asphalt Technology. International Journal of Pavement Engineering. 15(1) 79–94.
[2] Guo, Naisheng et al 2014 Laboratory Performance of Warm Mix Asphalt Containing Recycled Asphalt Mixtures. Construction and Building Materials. 64 141–49.
[3] Zhang and Jiupeng et al 2015 Viscosity-Temperature Characteristics of Warm Mix Asphalt Binder with Sasobit®. Construction and Building Materials. 78 34–39.
[4] Zhang, Zhen, Li-ping Liu, and Wen Tang 2009 Research on Performance of Evotherm Warm-Mix Asphalt. Journal of building materials. 12(4) 438–41.
[5] Xu, Shifa, Xiaohui Luo, and Zhong Sun 2008 Performance Evaluation and Comparison of SBS Emulsion Warm Mixture and Hot SBS Modified Asphalt Mixture. J Beijing.

[6] LI, Zhong-qiu, and Jing-kun MA 2004 In-Door Experiment on Sasobit Modifying Additive. Journal of highway and transportation research and development. 21(10) 26–29.
[7] Zhang, Rui, and X M Huang 2007 Performance Analysis of Asphalt and Asphalt Mixture with Sasobit. Journal of traffic and transportation engineering. 7(4) 54–57.
[8] Ji, Xiao-ping, and Yun-long Sun 2010 Experimental Research of Warm Mix Asphalt with Sasobit. Journal of Wuhan University of technology. 32(14) 75–78.
[9] Zhou, Yan, Shuan-fa CHEN, and Mu-lian ZHENG 2010 Research on Mixing and Compaction Property of Warm Mix Asphalt. Journal of Wuhan University of Technology. 32(1) 61–64.
[10] WU, Chao-fan, Meng-lan ZENG, Mao-wen WANG, and Yang Xia 2010 Determination of the Mixing and Compaction Temperatures for Warm Mix Asphalt with Sasobit [J]. Journal of Hunan University. Natural Sciences 8 1–5.
[11] Wu, Chaofan, Menglan Zeng, Changhe Lu, and Fei Li 2012 Effect of Warm-Mix Additive on Penetration and High-Temperature Performance Grade of Asphalt Binder. Journal of Highway and Transportation Research and Development. 29(1) 16–21.
[12] Yang, Xia, ZENG Menglan, Z H U Yuanfeng, and Wu Chao-fan 2009 Experimental Research on Road Usage Performance of Sasobit Warm Mix Asphalt. Highway Engineering. 34(2) 22–25.
[13] Maowen, WANG, W U Chaofan, and Z H U Yuanfeng 2009 Research on Performances of Modified Asphalt and Warmmixing Asphalt Mixture with Sasobit. Highway. 11 175–79.
[14] Hurley, Graham C, and Brian D Prowell 2005 Evaluation of Sasobit for Use in Warm Mix Asphalt. NCAT report. 5(6) 1–27.
[15] ASTM D5 2013 Standard Test Method for Penetration of Bituminous Materials (West Conshohocken: ASTM Standard). 5-8
[16] D4402M–12 A 2012 Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer American Society for Testing and Materials West Conshohocken: ASTM Standard.
[17] ASTM D 2012 2872-12, Standard Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test).
[18] ASTM D7175 2015 Stand Test Method Determ Rheol Prop Asph Bind Using a Dyn Shear Rheometer West Conshohocken: ASTM Standard.
[19] Ghuzlan, Khalid A, and Mohammad O Al Assi 2017 Sasobit-Modified Asphalt Binder Rheology. Journal of Materials in Civil Engineering. 29(9) 4017142.