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Influence of Additive On bitumen Viscosity Properties at High and Mid-Range Temperatures

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ABSTRACT

The viscosity of bitumen 80/100 penetration grade is the measure of its resistance to flow which affects resistance to deformation of the mixture. This study reviewed the bitumen modification process in relation to warm mix asphalt (WMA) technology, using Sasobit wax (S) as a modifier. The study investigated the viscosity measurements of bitumen and modified bitumen, using the Brookfield viscometer. The binders mixed with various percentage of the wax S 1%, 2%, 3%, 4%and 5% were investigated. The results from the study showed the viscosity of the binder decreasing at higher temperatures while at midrange temperatures the viscosity increases with an increase in the additive. This study has provided a valuable data on the effect of the additive S on increasing the dynamic viscosity of the binder at low temperature and decreasing the kinematic viscosity at high temperature, been attributed to the presence of the S wax with high hydrocarbons molecular content in the binder, which is expected to improve the viscosity properties of the modified binder and enhance its resistance to deformation when used in warm asphalt concrete mixtures.

Keywords: *Viscosity, Sasobit, bitumen, viscometer, and warm mix asphalt*

1. INTRODUCTION

Bitumen is black cementius, thermo-visco-elastic material where temperature and rate of load application have a great influence on their behavior. They are classified as rheological materials since their viscosity stress and strain response is both time and temperature dependent [1]. The binder consistency and hence ability to sustain and hold its fundamental cementing mechanism changes depends on its viscosity. In the study bitumen with penetration grade 60/70 were modified with Sasobit wax (S), which is obtained from coal gasification using the Fischer-Tropsch process, with long-chain hydrocarbon content range [2].

The viscosity of bitumen is its internal resistance to flow or measure of it resistance to deformation by either shear stress or tensile stress and a significant parameter in determining the bitumen rheology and engineering properties [3]. The viscosity of bitumen shows a complex response under different conditions and it influences the mixing, laying and compaction of asphalt mixtures as well as the pavement performance. In view of these reasons viscosity measurements have been used to classify bitumen, but due to the visco-elastic nature of bitumen the results lack uniformity as the bitumen source and molecular content might differ [4].

Most of the roads in Malaysia are constructed as asphalt concrete pavements, which mainly consist of bitumen, and aggregate. The bitumen though in smaller quantity as compared to the aggregate serves as a binder to the pavement materials. The recent increase in traffic volume, resulting to intense loading of the pavements across the country with severe consequences leading to permanent deformation of the pavement is of great concern. This has prompted a strong interest in developing alternative means of enhancing the performance of the bitumen used in the production of Asphalt concrete; these include modification of the binder with either organic additive or polymers.

The performance of asphalt pavement is mainly governed by the properties of the binder. Bitumen exhibit's a visco elastic behavior hence in pavement when exposed to high temperature permanent deformation (Rutting) takes place along the wheel path of the pavement [5]. On the other hand, bitumen in pavement at low temperature exhibits brittleness and pavement cracking occurs.

A study by Sasol International indicated a significant drop in the viscosity of the binder when modified with S at high temperature [6]. Polymers and additives are oftenly used to enhance the performance of bitumen, and experimentation with the use of S in asphalt concrete started in early 1990s and this technology called warm mix asphalt (WMA) has been claiming to improve the engineering properties of bitumen [1].Early research and marketing efforts have mainly focused on the environmental benefits and the reduced energy consumption of the technology and not as much on the viscosity and consistency of the modified binder at high and low temperature. This study investigated the viscosity at production and working temperature of neat and modified bitumen. In this study the commercial additive S was used to lower viscosity of the binder at high temperature, making it less susceptible to high temperature damage, and flow improver at low temperature [6].

A study at the National centre for asphalt technology U.S.A in 2006 indicated adding Sasobit wax to bitumen effects its rheological properties [7].Also

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Xiaohu and Isakson (1997) studied the influence of styrene- butadiene- styrene (SBS) polymer modification on bitumen viscosity. Results from the study showed SBS modified bitumen to have increase degree of non-Newtonian behavior [4]. The linear SBSmodifiedbitumens demonstrated a high degree of shear thinning behavior compared to base bitumens. Also a study on bitumen characteristics conducted at the highway laboratory UTM, indicated Sasobit increasing the softening point and decreasing penetration [8]

2. RESEARCH SCOPE

The study investigated the influence of additive Sasobit wax on the viscosity of bitumen 80/100 penetration grade. The penetration and softening of the binder with or without the wax additive was investigated in accordance to ASTM [9].

3. EXPERIMENT AND MATERIAL

For this study neat bitumen PEN 80/100 from an unknown source and pellets of Sasobit wax (S) supplied by Sasol international was used for the study. Neat and modified bitumen total of30 samples, with various percentage of S (1-5%) were investigated in the study.

Some physical-chemical characteristics of the bitumen used in this study are presented in Table 1.

Tables 1

Test	**ASTM**	**Bitumen**
Penetration (dmm)	D5-97	89
Softening point (C)	D36-95	47

3.1 Viscosity

The viscosity of the binder was measured using the Brookfield viscometer; the equipment was used to measure the viscosity characteristics of the neat and modified binder PEN 80/100 (with and without S). This study determined influence of the additive on the viscosity of the binder at midrange and high temperatures, which. The viscosity of each bitumen sample with and without S was measured at various test temperatures and at a shear rate of 6.8/s. This shear rate was selected because it conforms to the rotational speed of 20rpm with the Brookfield Spindle 27 recommended for Super pave (SHRP). The kinematic viscosity was measured at 135^{o}C while the dynamic viscosity was not measured at 60^{o}C as required; this was due to hardening of the modified binder hence it was tested at 75^{o}C

3.2 Penetration and softening point

The penetration grade of the neat bitumen with and without S was investigated using the penetro meter in accordance with ASTMD5-97 specification, while the softening point of the various test samples was determined using the ring and ball test in accordance to ASTM D36-95 specifications.

4. RESULTS

The study investigated the viscosity of bitumen 80/100 with various % of additive by the means of the brooks field viscometer. The primary objective of the study was to determine the viscosity and shear stress of the modified bitumen. The Table 1 below shows the combination of bitumen and various % of S. From the study there is a decrease in the viscosity of the binder at high temperature as the S was increased and this could be attributed to the presence of the additive.
It can also be seen from Table 2 and Figure 1 below that the addition of the S additive reduced the viscosity.

Fig 1: viscosity at high temperature

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Table 2: Bitumen 80/100 Viscosity at 150°C

Des.	**B+ 0%S**	**B + 1%S**	**B+ 2%S**	**B + 3%S**	**B + 4%S**	**B + 5%S**
CP	300	300	200	110	100	100
SS	20.4	20.4	13.6	7.5	6.8	6.8
SR	6.8	6.8	6.8	6.8	6.8	6.8
T %	0.3	0.3	0.2	0.1	0.1	0.1

Where B is bitumen and S is sasobit

It can also be seen from Table 3 below that the addition of the S additive reduced the viscosities of the various binder mixes at 135°C.

Table 3: Bitumen 80/100 viscosity at 135°C

Des	**B+ 0%S**	**B + 1%S**	**B+ 2%S**	**B + 3%S**	**B + 4%S**	**B + 5%S**
CP	450	410	300	200	200	100
SS	30.6	27.9	20.4	13.6	13.6	6.8
SR	6.8	6.8	6.8	6.8	6.8	6.8
T %	0.45	0.4	0.3	0.2	0.2	0.2

Fig 2: Viscosity at High Temperature

From the study the addition of S at 135°C temperature indicated a reduction in the viscosity As presented in Figure 2 above.

From the Table 4 below the study indicates that the addition of S at 120°C resulted in a decrease in viscosity of the binder as the additive content was increased

Table 4: Bitumen 80/100 Viscosity at 120°C

Des	B+ 0%S	B + 1%S	B + 2%S	B + 3%S	B + 4%S	B+ 5%S
CP	980	980	950	950	700	600
SS	66.6	66.6	64.62	64.62	47.6	40.8
SR	6.8	6.8	6.8	6.8	6.8	6.8
T%	0.98	0.98	0.95	0.95	0.7	0.6

From the study the addition of S at 120°C temperature indicated a reduction in the viscosity of the binder as can be seen in Figure 3 below;

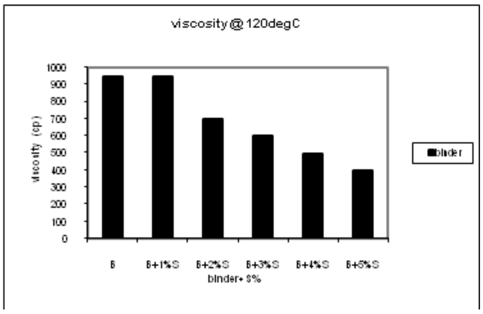

Fig 3: Viscosity Trends

An ideal binder for road application should posses' constant properties high temperature susceptibility to change to a viscous fluid for effective mixing and compaction and low temperature susceptibility over the ambient temperature range. However, bitumens do not behave in that manner but exhibit a continuous change in their viscosity over the whole operational temperature. The addition of S at high temperature resulted in the decrease in viscosity, which should show increase resistance to rutting and thermal cracking at high and low temperatures, respectively.

The modified bitumens have indicated an improvement in their properties this could be attributed to the additive networks and entanglements as well as interactions of the S aliphatic hydrocarbons with bitumen that inhibits association or dissociation of molecules as temperature changes. At low temperature changes the bitumen shows an elastic behavior. From the study the addition of S to the binder when investigated using the Brookfield viscometer indicated an increase in viscosity at 100°C as can be seen in Table 4 below;

Table 5: Bitumen 80/100 Viscosity at 100°C

Des.	**B+ 0%S**	**B + 1%S**	**B + 2%S**	**B + 3%S**	**B + 4%S**	**B + 5%S**
CP	225	277	330	345	400	405
SS	153	188	224	234	272	275
SR	6.8	6.8	6.8	6.8	6.8	6.8
T %	2.25	2.77	3.3	3.4	4.0	4.05

The viscosity test at 100°C indicated an increase viscosity as the additive was increased in the binder as could be seen in Figure 4 below;

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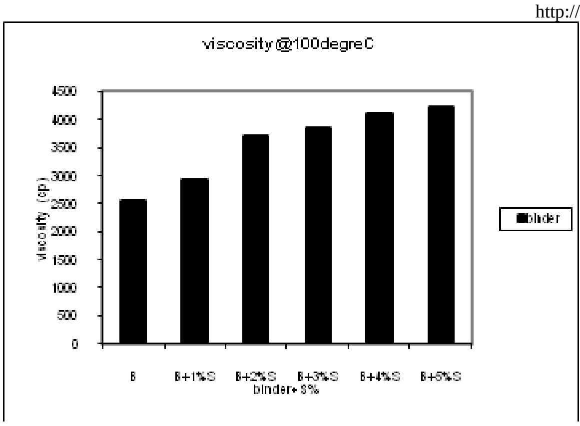

Fig 4: Viscosity Trends

From the study at midrange temperature of 75^{o}C the Viscosity of the binder increases with an increase in S as can be seen in table 6 and Figure 5 below

Table 6: Bitumen 80/100 Viscosity at 75^{o}C

Des.	B+ 0%S	B + 1%S	B + 2%S	B + 3%S	B + 4%S
CP	2500	25500	30100	30300	45100
SS	1911	1904	2251	2333	3204
SR	6.8	6.8	6.8	6.8	6.8
T %	25.0	25.5	30.1	30.9	45.1

It can also be seen in Figure 4 below that the addition of the additive increased the viscosity of the modified bitumen at the midrange temperature of 75^{o}C; it indicated that the viscosity of the binder increases with an increase in the % of S.

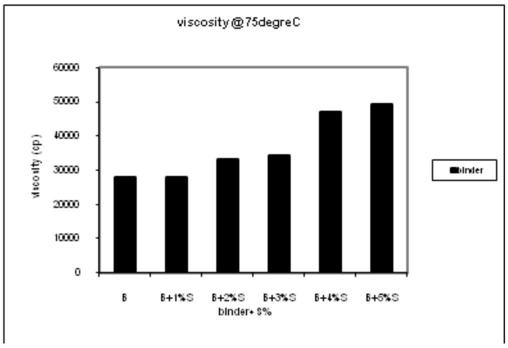

Fig 5: Dynamic Viscosity

5. CONCLUSSION

This study has indicated that the additive S increases the dynamic viscosity of the binder at mid-range temperature and decreases the kinematic viscosity at high temperature. The addition of S significantly reduces the viscosities of the binder at temperatures above 100^{o}C there by providing low temperatures working environments. This advantage has enabled the production of asphalt concrete at low temperatures, using the warm mix asphalt technology (WMA), which is currently been investigated, at the highway laboratory at the university of technology Malaysia. The S wax used in this study was to modify the binder, subsequently used to lower the mixing and compaction temperatures in asphalt concrete. Its effect on the viscosity of the binder guarantees an efficient coating of the aggregate by the binder. Also the addition of S at midrange temperature of 75^{o}C indicated an increase in viscosity as the S% was increased. It is a wax, which recrystallizes in the binder on cooling, there by increasing the viscosity of the binder at lower temperatures; this enhances the flow of the binder. Base on the penetration test conducted on the 3% S modified binder could be categorized as PG68-22.

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