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# Viscosity Characteristics of Modified Bitumen

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## ABSTRACT

The effect of commercial additive Sasobit wax (S) on the viscosity characteristics of bitumen 60/70-penetration grade is yet to be fully understood. The viscosity of bitumen is the measure of its resistance to flow which affects workability, and resistance to deformation of the mixture. This study reviewed the bitumen modification process in relation to warm mix asphalt (WMA) technology, using S as a modifier. The study investigated the viscosity measurements of 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, Rheology, and Modification*

## 1. INTRODUCTION

Bitumen is a thermo-visco-elastic material where temperature and rate of load application have a great influence on their behavior [1]. They are classified ass rheological materials since their viscosity stress and strain response is both time and temperature dependent [2]. The binder consistency and hence ability to sustain and hold its fundamental cementing mechanism changes depending on its viscosity [3]y. In the study bitumen with penetration grade 60/70 were modified with sasobit wax (S), which is obtained from coal gasification using the Fischer-Tropics process, with long-chain hydrocarbon [4].

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 of asphalt concrete; it influences the workability and resistance to mix [2]. 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 [5]. In view of these reasons viscosity measurements have been used to classify bitumen, but due to the visco-elastic nature of bitumen's the results lack uniformity as the bitumen source and molecular content might differ [6]

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 too 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 additives like S or polymers.

Bitumen is a rheological, thermoplastic and viscoelastic material. Its deformation characteristics vary not only with load, but also with time rate of load application and temperature. It is neither elastic nor viscous in behavior. At low temperature it exhibits elastic behavior while at high temperature it exhibits viscous behavior [7]. The neat binders lack the proper viscous-elastic balance that usually occurs due to an effective elastic network created by molecular association. It is hypothesized that proper visco-elastic balance can be formed by creating molecular entanglement in a bitumen through the use of high molecular weight polymeric additives.

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. On the other hand, bitumen in pavement at low temperature exhibits brittleness and pavement cracking occurs.

This study investigated the viscosity at production and working temperature of neat and modified bitumen's. 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. The additive S is introduced to warm mix

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asphalt (WMA) by blending with the binder at the terminal or contractor's tank. The recommended addition rate is 0.8% to 3% by mass of the binder according Sasol report (2003). At high temperatures S lowers the viscosity of the binder such that working temperatures decrease by 45ºC [2].

The additive has a congealing temperature of about 100ºC and is completely soluble in binders at temperatures lower than 110ºC, at temperatures below its melting point, it forms a crystalline network structure in the binder that is reported to provide added stability as the bitumen stiffens at low temperature [1].

Viscosity is also termed to be a measure of deformation of fluid due to shear stress or tensile stress, and is a fundamental parameter in the investigation of the rheological properties of bitumen. Previous researches included studied the effect of wax on the basic and rheological properties of bitumen with similar penetration grades [8]. Results from the study indicated good correlation between the wax content in bitumen under a high temperature environment.

Edwards studied the rheological properties of commercial waxes and poly phosphoric acid in bitumen at high and medium temperature performance. Results from the study showed adding polyethylene wax to bitumen effects its rheological properties at medium and higher temperatures. Also the influence of styrene-butadiene- styrene (SBS) polymer modification on bitumen viscosity. Results from the study showed SBS modified bitumen's to have increase degree of non-Newtonian behavior. The linear SBS modified bitumen's demonstrated a high degree of shear thinning behavior compared to base bitumen's.

## 2. EXPERIMENT AND MATERIAL

For this study neat bitumen PEN 60/70 from an unknown source and pellets of sasobit wax (S) supplied by sasol international was used for the study. Neat and modified bitumen totally 30 samples, with various content of S 0%, 1%, 2%, 3%, 4%, and 5% were investigated in the study.

Some physical-chemical characteristics of the bitumen used in this study can be seen in tables I below;

**Table 1**

| s | ASTM | Bitumen |
|---|---|---|
| Penetration (dmm) | D5-97 | 67 |
| Softening point ($^oC$) | D36-95 | 49 |

**Viscosity:** The viscosity of the binder was measured using the brooks field viscometer; the equipment was used to measure the viscosity characteristics of the neat and modified binder PEN60/70 (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 at a shear rate of 6.8/s. This shear rate was selected because it conforms to the rotational speed of 20rpm with the brooks field 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

### 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.

## 3. RESULTS

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 viscosities of the various binder mixes at 150$^o$C.

**Table 2:** Bitumen 60/70 Viscosity at 150$^o$C

| Des. | B+ 0% S | B + 1% S | B+ 2% S | B + 3% S | B + 4% S | B + 5% S |
|---|---|---|---|---|---|---|
| CP | 200 | 200 | 150 | 110 | 100 | 100 |
| SS | 13.6 | 13.6 | 10.2 | 7.5 | 6.8 | 6.8 |
| SR | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| T % | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |

Where B is bitumen and S is sasobit

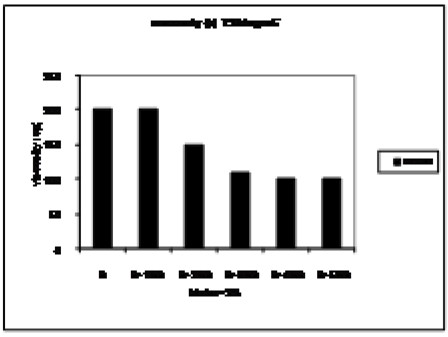

**Fig. 1:** Viscosity at high temperature

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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 60/70 Viscosity at 135°C

| **Des** | **B+ 0%S** | **B + 1%S** | **B+ 2%S** | **B + 3%S** | **B + 4%S** | **B + 5%S** |
|---|---|---|---|---|---|---|
| CP | 410 | 400 | 300 | 200 | 200 | 100 |
| SS | 27.9 | 27.2 | 20.4 | 13.6 | 13.6 | 6.8 |
| SR | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| T % | 0.3 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 |

From the study the addition of S at 135°C temperature indicated a reduction in the viscosity of the binder as can be seen in Figure 2 below;

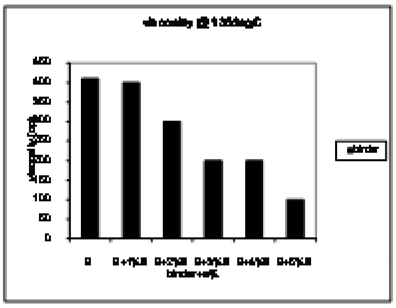

**Fig 2:** kinematic viscosity

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 60/70 Viscosity at 120°C

| Des | B+ 0%S | B + 1%S | B + 2%S | B + 3%S | B + 4%S | B+ 5%S |
|---|---|---|---|---|---|---|
| CP | 950 | 950 | 700 | 600 | 500 | 400 |
| SS | 64.62 | 64.62 | 47.6 | 40.8 | 34.0 | 27.2 |
| SR | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| T% | 0.7 | 0.7 | 0.6 | 0.6 | 0.5 | 0.4 |

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;

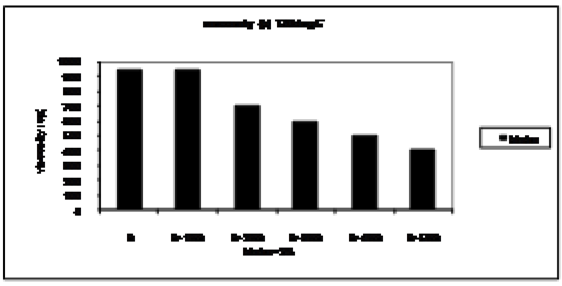

**Fig 3:** viscosity trends

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, bitumen's do not behave in that manner but exhibit a continues 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 bitumen's 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 60/70 Viscosity at 100°C

| **Des.** | **B+ 0%S** | **B + 1%S** | **B + 2%S** | **B + 3%S** | **B + 4%S** | **B + 5%S** |
|---|---|---|---|---|---|---|
| CP | 2550 | 2920 | 3700 | 3850 | 4110 | 4200 |
| SS | 173.5 | 198.6 | 251.7 | 261.9 | 278.9 | 285.7 |
| SR | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| T % | 2.5 | 2.5 | 2.7 | 2.7 | 3.0 | 3.1 |

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;

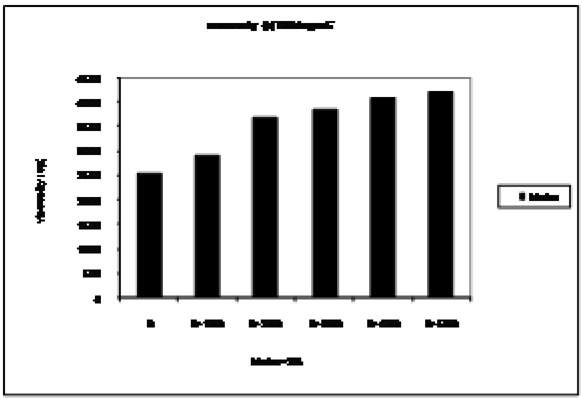

**Fig 4:** viscosity trends

From the study at lower temperature of 60°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 60/70 Viscosity at 60°C

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| Des. | B+ 0%S | B + 1%S | B + 2%S | B + 3%S | B + 4%S | B + 5%S |
|---|---|---|---|---|---|---|
| CP | 28100 | 28000 | 33100 | 34300 | 47100 | 49300 |
| SS | 1911.6 | 1904.8 | 2251.7 | 2333.3 | 3204.0 | 3353.7 |
| SR | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| T % | 25.0 | 25.0 | 31.1 | 31.1 | 42.1 | 42.1 |

It can also be seen in Figure 5 below that the addition of the additive increased the viscosity of the modified bitumen at the lower temperature of 60$^o$C,it indicated that the viscosity of the binder increases with an increase in the % of S.

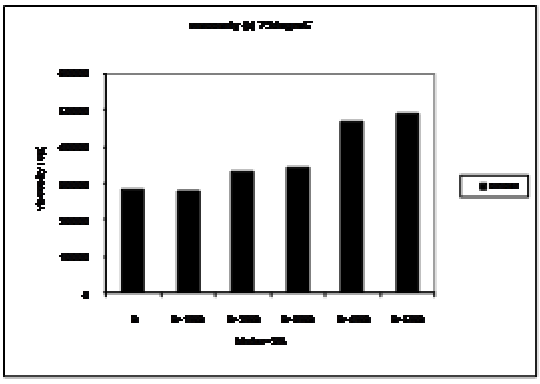

**Fig 5:** Dynamic viscosity

## 4. CONCLUSSION

This study has indicated that the additive S increases the dynamic viscosity of the binder at low 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. The additive 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 and a good workability of the asphalt mixture at lower temperatures compared to the conventional hot mix asphalt (HMA). Also the addition of S at low temperature of 60 $^o$C indicated an increase in viscosity as the S% was increased. It is a wax, which recrystallizes in the binder on cooling, thereby 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 PG76-22.

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