LABORATORY INVESTIGATION OF WARM ASPHALT BINDER PROPERTIES – A PRELIMINARY ANALYSIS

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Abstract: With increasing concerns of global warming and increasing emissions, the asphalt industry is making a constant effort to lowering its emissions by reducing the mixing and compaction temperatures of the asphalt mixture without affecting the properties of the mix. Several proprietary chemicals are available in the industry that can help reduce the mixing and compaction temperatures. These chemicals work in different ways to either reduce the viscosity of the binder or to allow better workability of the mix at lower temperatures due to some modifications in the binder. A significant reduction of required heat can be achieved in most cases. Several studies have been conducted evaluating the properties of the warm mix asphalt; however, properties of the binders containing these chemicals have not been studied in great detail. This paper presents the tests conducted on 3 different binders from different sources and performance grades. Warm asphalt binder was produced using two of the available processes, and tests were conducted on the binders using the viscometer and the Dynamic Shear Rheometer. The binders were then stored at 120 ^{o}C for 3 days to simulate plant shutdowns, and the tests were repeated. It was observed that one of the processes significantly increases the viscosity, whereas another significantly lowers the viscosity of the binder.

INTRODUCTION

Warm asphalt has been gaining increasing popularity in the recent years. Apart from the obvious advantages like reduced fuel consumption and reduced emissions in the plant, there are several other advantages of using warm asphalt like longer paving 'seasons', longer hauling distances, reduced wear and tear of the plants, reduced ageing of binders, reduced oxidative hardening of binders and thus reduce cracking in the pavements, ability of opening the site to traffic sooner, etc. *(Hurley and Powell, 2006)*. With the availability of several proprietary chemicals and processes to produce warm asphalt, it is now possible to produce warm asphalt without affecting the properties of the mix. Some of the most common processes / chemicals available today are as described below.

Aspha-Min®: It is a Sodium – Aluminum – Silicate which has been hydro thermally crystallized as a very fine powder. It contains about 21% crystalline water by weight. Aspha-Min® is added to the mixture at a rate of 0.3% by weight of the mixture. By adding it to the mixture at the same time as the binder, a very fine water spray is created as all the crystalline water is released, which causes volume expansion in the binder, thereby increasing the workability and compatibility of the mixture at lower temperatures. It has been reported, by the manufacturer, that a reduction of about 40 to 50 ^{o}F has been observed. This specific property of Aspha-Min® is maintained over a long duration of time *(Eurovia Services)*.

Evotherm™: It uses a chemical additive technology and a "Dispersed Asphalt Technology", (DAT), delivery system. The producer states that by using this technology a unique chemistry customized for aggregate compatibility is delivered into a dispersed asphalt phase (emulsion). During production, the asphalt emulsion with Evotherm chemical package is used in place of the traditional asphalt binder. The emulsion is then mixed with the aggregate in the HMA plant. The manufacturer reports that this chemistry provides better aggregate coating, workability, adhesion, and improved compaction with no change in materials or job mix formula required. In addition, they report that field testing has demonstrated a 100 °F reduction in production temperatures *(MeadWestvaco)*.

Sasobit®: It is a long chain aliphatic hydrocarbon (chain lengths of 40 – 115 carbon atoms) obtained from coal gasification using the Fischer – Tropsch process. The melting point of Sasobit® is around 185 to 240 ^{o}F. Sasobit® forms a homogeneous solution with the base binder on stirring, and produces a marked reduction in the binder's viscosity. Reductions of about 50 to 90 ^{o}F in the mixing and handling temperatures of the mixture have been reported by the producer. After crystallization, Sasobit® forms a lattice structure in the binder which is the basis of the structural stability of the binder containing Sasobit® (*Sasol Wax)*.

WAM-Foam®: In this process, the binder is formed using two separate binder components in the mixing stage. A soft binder is mixed with the aggregate in the first stage at approximately 230 °F to achieve full aggregate coverage. The hard binder component is mixed in a second stage into the pre-coated aggregates in the form of foam. The hard binder foam combines with the soft binder to achieve the final required composition and properties of the binder. The success of WAM-Foam depends on careful selection of the soft and hard components. The initial coating of the aggregate in the first mixing stage is vital to prevent water from reaching the binder and aggregate interface *(Federal Highway Administration)*.

MATERIALS AND EXPERIMENTAL DESIGN

In this project, two of the above mentioned processes were selected in making the warm asphalt binder (Process 1 and Process 2). In process 1, the additive was added at 0.3% by weight of the mixture. However, since only binder tests were conducted, 6% binder content in the mixture was assumed, and the entire quantity of the additive was added to the binder. In process 2, the additive was added at 1.5% by weight of the binder. Warm asphalt binder was produced using three different binders, Binder I, PG 64 -22, Binder II, PG 64 -22 and Binder III, PG 58 -28. Figure 1 shows the experimental design followed for this research.

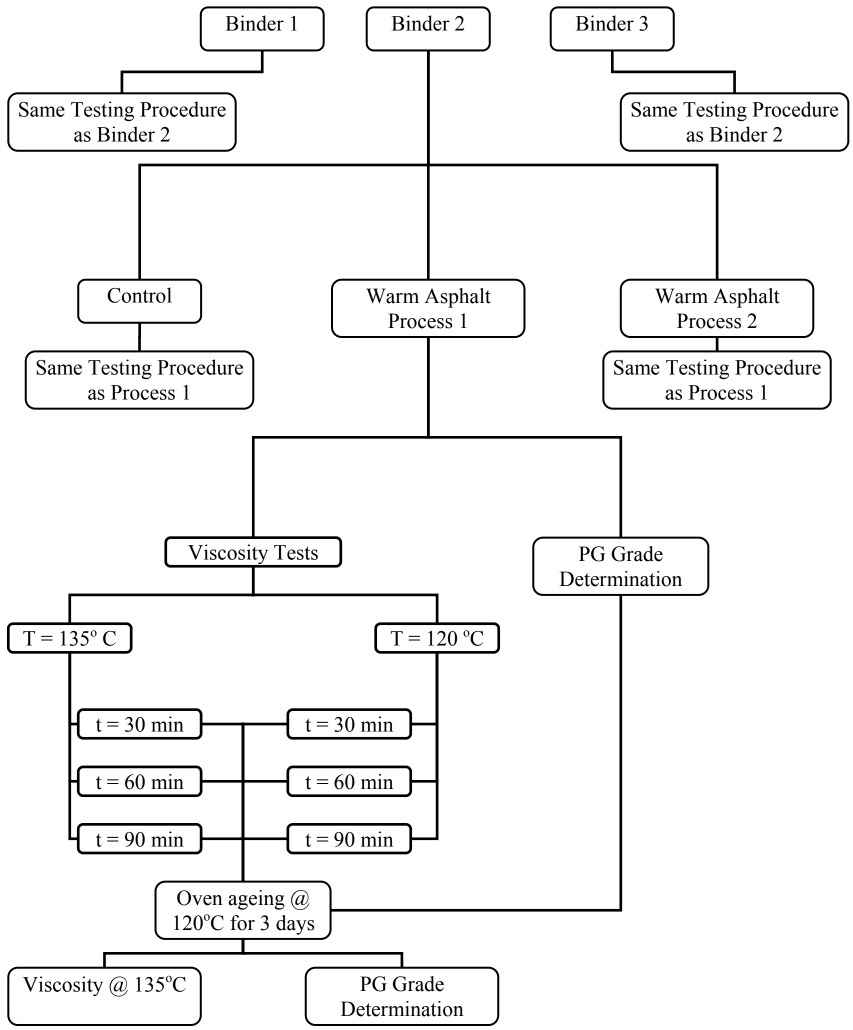


Figure 1 Experimental design.

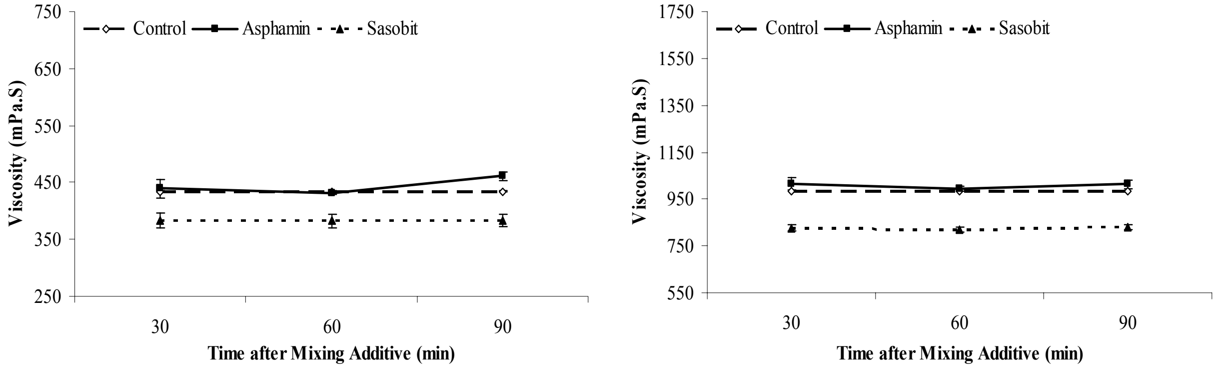
Viscosity of the warm asphalt binders were measured at 135 °C, the standard test temperature, and at 120 °C, which is the mixing temperature generally used for warm mix asphalt. To determine the effect of time on the viscosity after mixing the warm asphalt additives, viscosity was measured after 30, 60 and 90 minutes of adding the warm asphalt additive. The SHRP PG grade determination test was run on the binder using the Dynamic Shear Rheometer (DSR) to determine the G*/sinδ at the PG temperature and the failure temperature for the binder.

To simulate plant shutdowns, the binders were aged in the oven at 120 °C for 3 days. After 3 days, the binders were removed, and the viscosity was measured at 135 °C and the SHRP PG grade determination test was run on the stored binder.

RESULTS AND DISCUSSIONS

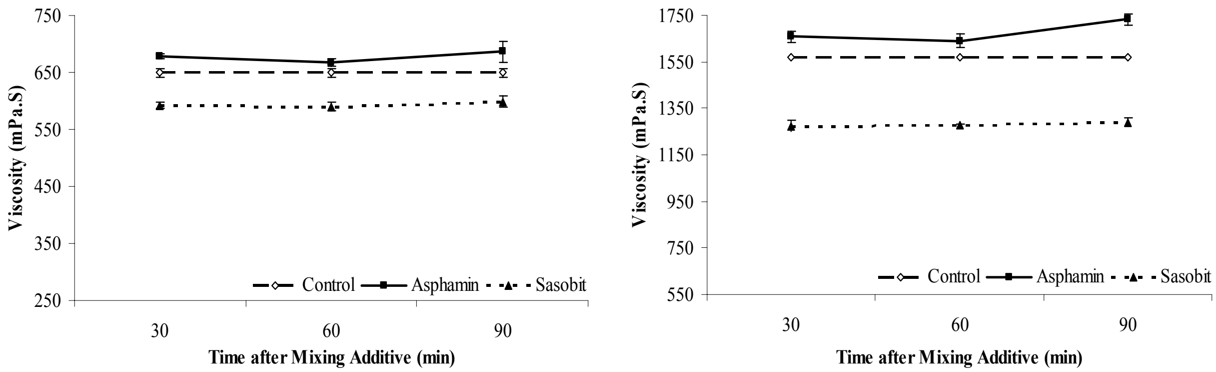
Figures 2 – 4 show the viscosity of the virgin and warm asphalt binders at 135 °C and 120 °C. The effect of time after mixing the warm asphalt additives are also seen in these graphs. It was observed that with Process 1, the viscosity significantly increased compared to the base binder.

However, process 2, seems to reduce the viscosity significantly. This was observed with all the binders at 135 ^oC and at 120 ^oC.



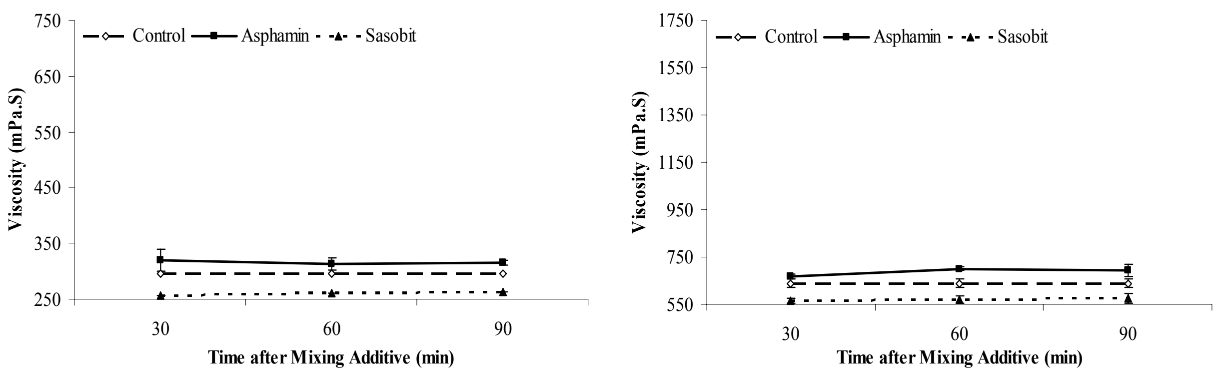
(a) (b)

Figure 2 Viscosity of Binder I - (a) 135 ^oC and (b) 120 ^oC



(a) (b)

Figure 3 Viscosity of Binder II - (a) 135 ^oC and (b) 120 ^oC



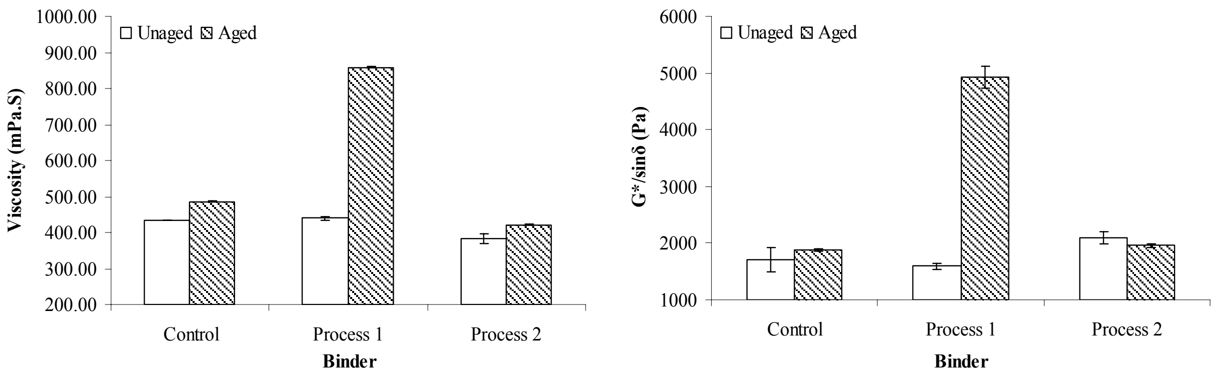
(a) (b)

Figure 4 Viscosity of Binder III - (a) 135 ^oC and (b) 120 ^oC

Also, the viscosity did not seem to change for up to 90 minutes after the warm asphalt additives were added with Process 2. However, with Process 1, the viscosity of the binder significantly increased generally after 90 minutes of mixing the additive. The reason for the increase in the viscosity with Process 1 can be attributed to the addition of solid material in the form of a fine powder to the binder, which acts as a filler. There could be a slight decrease in the viscosity initially due to foaming of asphalt, however, the foaming decreases with time, and thus the increase in viscosity after about 60 – 90 minutes.

Effect of Ageing

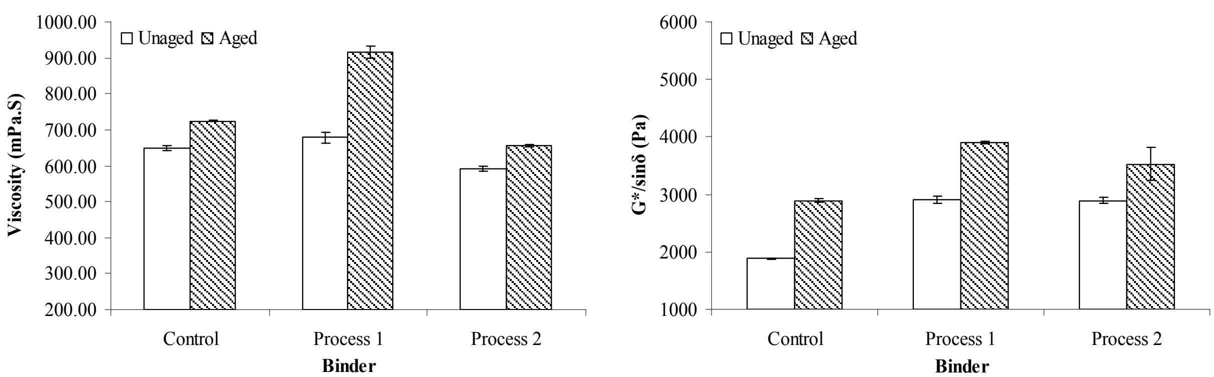
All the binders were aged in the oven at 120 ^oC for 3 days to simulate plant shutdowns by pouring the binders in small containers with lids on top, and leaving them undisturbed in the oven for 3 days. After 3 days, the binders were tested for viscosity and the SHRP PG grade determination test was performed on the binders. Figures 5–7 show the effects of ageing on the viscosity of the binders, and the effect of ageing on the G*/sinδ of the binders at the PG temperature.



(a) (b)

Figure 5 Binder I before and after ageing - (a) Viscosity and (b) DSR

As seen in Figure 5, Process 1 significantly affects the ageing of Binder I. Both, the viscosity and the G*/sinδ significantly increase after ageing. The reason for this can not be explained at this stage. The effect of Process 1 does not seem to be as significant on the ageing characteristics of Binders II and III.



(a) (b)

Figure 6 Binder II before and after ageing - (a) Viscosity and (b) DSR

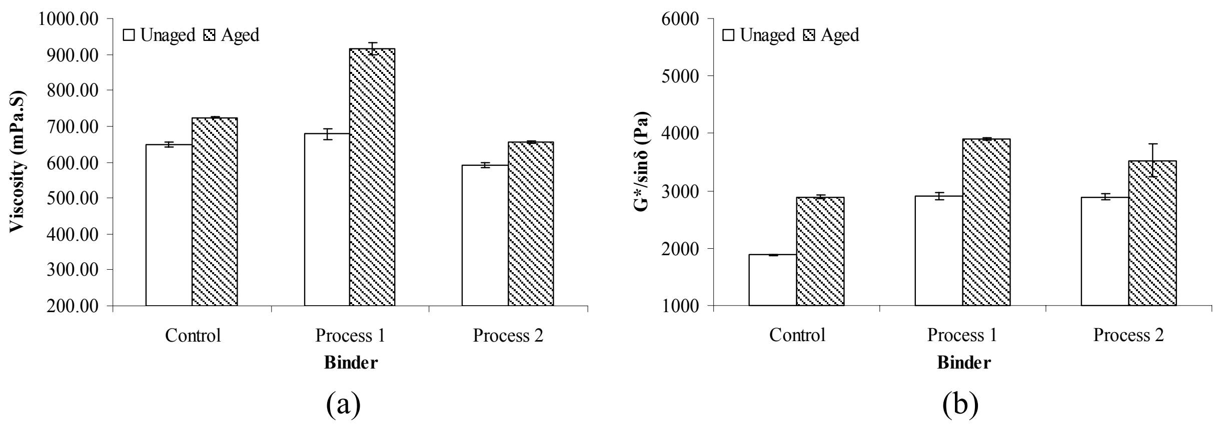


Figure 7 Binder III before and after ageing - (a) Viscosity and (b) DSR

When unaged Binder II is used, the G*/sinδ increases significantly with both Process 1 and Process 2. However, this increase is not significant with Binders I and III. Therefore, it appears that the warm asphalt chemicals interact differently with different binders based on the chemistry of the additives and the binders.

CONCLUSIONS

The following conclusions can be drawn from this limited study:

- Process 1 increases the viscosity of the base binder significantly. This increase is attributed to the addition of fine solid material to the binder, which acts like a filler. With time, the increase in the viscosity is more due to the decrease in foaming.
- Process 2 significantly lowers the viscosity of the base binder. There was a noticeable reduction in the viscosity with Process 2 when the base binder has a higher viscosity.
- The viscosity of the binder remains the same for up to 90 minutes after the addition of warm asphalt additive in Process 2.
- Process 1 causes a significant increase in viscosity and G*/sinδ after ageing in Binders I and II.
- Process 2 does not seem to affect the ageing of the binders.
- Each of the additives / processes is dependant on the chemical properties of the asphalt binder. Thus, each combination should be evaluated before use.

REFERENCES

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