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Rheological Characteristics of Waste Polyvinyl Chloride-Bitumen Composites: Part III

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Abstract— *Waste Polyvinyl chloride-bitumen composites were prepared in the molten state by addition waste PVC pipes to commercial bitumen in different concentrations. The original material of the pure bitumen and bitumen composites are rheologically characterized. The viscoelastic properties such as shear compliance, torque and viscosity were measured and compared. These properties were studied using an ARES- Rheometer (Rheometric Scientific, Co.) equipment. The measurements were performed in the dynamic mode, plate-plate geometry of 25 mm diameter over the temperature range from –10 to 60°C and angular frequency, ω varied from 10^2 to10^{-1} radian/s. The results are compared at reference temperatures10 and 60°C over a wide range of ω . The results evidence that the incorporation of the waste PVC into bitumen enhances the dynamic viscosity. The results evidence that the incorporation of the waste PVC into bitumen enhances the torque and the viscosity. So, the stability of the bitumen composites is more noticeable at 60°C.*

Keywords: Waste Polyvinyl chloride-bitumen composites, dynamic viscosity.

1. INTRODUCTION

The chemical composition of bitumen is very complex. Bitumen is a complex mixture of organic and inorganic compounds. Such compounds may be separated into asphaltenes and maltenes [1-9].The asphaltenes are the most polar fraction and have the highest molecular weight, giving its dark color to the bitumen. The maltene fraction consists of polar aromatics, naphthene aromatics, and saturates. The ratio of the asphaltenes to the maltenes has a significant effect on the viscoelastic properties of bitumen and, consequently, on its performance as road paving binders.Thus, road pavements may show different distresses depending on temperature-for example, rutting (or permanent deformation at high temperatures) related to the viscosity of the bitumen matrix, and low-temperature cracking, as a result of brittle fracture of the glassy bitumen matrix [10]

The concept of using mineral fillers in the modification of bitumen has been recognized for a long time because of their cost and stiffness advantages. However, concerns have been raised that mineral fillers may cause mastics to exhibit excessively brittle behavior and result in cracking at low temperatures.Recently, considerable attempts have been made on the modification of bitumen by soft fillers, such as polymers for road, roofing, and waterproofing applications[11-18]. The performance of these blends can be further achieved by controlling their rheology at a critical level with polymer addition. For this reason the study of the rheology for bitumen blends has considerable efforts from many researchers [19-24].

Nowadays, an increasing number of people are coming to the realization that plastic wastes are a potential worldwide source of raw materials. As we know, plastic wastes are usually commingled thermoplastics, that is, a mixture of polyethylene (PE), polyvinyl chloride (PVC), poly(ethylene terephthalate) (PET), polypropylene (PP), polystyrene (PS), and other common plastics. To recycle the commingled plastic waste in the form of blends is very attractive because it avoids the difficult task of separation [25].

The aim of this work is to recycle the waste PVC by using it as a modifier for the bitumen and study the rheological properties of the modified bitumen compared to the original material of the neat bitumen.

2. EXPERIMENTS PART

Materials and preparation

Bitumen blends were prepared from commercial bitumen and waste PVC pipes. Waste PVC were obtained from the garbage, sorted and shredded into coarse particles. The bitumen was melted in an oven followed by melting waste plastics and mixed homogeneously. The hot mixtures were then cast into a ring stamp with 25 mm diameter and 2 mm thickness for rheology testing .

Method

The rheological behavior was studied for pure bitumen and bitumen blends by using dynamic an ARES-Rheometer (Rheometric scientific) equipment. The measurements were performed in the dynamic mode, plate-plate geometry of 25 mm diameter over the temperature range from –10 to 60°C and angular frequency, ω varied from 10^2 to10^{-1} radian/s. With gap setting 2 mm and the actual gap size is read electronically and allows absolute moduli to be determined. The strain amplitude was1% to ensure the linear viscoelastic regime. 6 points per decade in frequency were obtained.

3. RESULTS AND DISCUSSIONS

Figure 1 represents the master curves of the torque at T_0 10 and 60°C as a function of frequency for the bitumen blends compared to pure bitumen. Figure 7 evidences that the incorporation of waste PVC into bitumen enhances the stiffness and strength of the bitumen. Because the torque is found to increase for bitumen blends compared to pure bitumen over all ω range in particular in the flow zone and it rises with the waste PVC content. Since the addition of 5% , 7% and 11% PVC leads to an increase in the torque by a factor about 3, 7, 8,9 and 12, respectively at 10°C and 0.6 rad/s. But at 0.006 rad/s, (the same T_0) the factor increases to 5, 10, 15, respectively. The difference between the torque of bitumen blends and neat bitumen is higher at T_0 60°C than at 10°C and that is significant particularly at the low frequencies of each mater curve. As shown in Figure 3 at T_0 10°C and ω= 0.001 rad/s the ratio of torque of bitumen-11%PVC to pure bitumen is 4 but at 60°C this ratio is 10. This because the stability due to the high stiffness of bitumen blends at high temperatures unlike pure bitumen.
Figure 2 shows the comparison between the dynamic viscosity ή of neat bitumen and those of bitumen blends as a function of frequency at low and high temperature (at T_0 10 and 60°C). ή increases with decreasing frequency and decreases with the temperature as shown in Figure 9. In this Figure ή reaches the Newtonian zone at low deformation rate of each T_0 at which it becomes independent on ω. In this zone ή is called melt viscosity η_0 (zero-shear viscosity) As shown in this Figure ή increases by the addition of waste PVC and it is observed to rise with increasing the waste PVC contents particularly in the Newtonian zone. As shown in Figure 9 at ω~0.01 rad/s (T_0 10°C) the values of η_0 are 10^1 , , 10^2 , 10^3 and 10^5 Pa.s for pure bitumen, bitumen-5%PVC, bitumen-7%PVC and bitumen-11%PVC, respectively. But the differences increases at the master curves of 60°C as shown in Figure 2. at ω~0.01 rad/s (T_0 60°C) the values of η_0 are 10^1 , 10^1 , 10^2 , 10^3 and 10^5 Pa.s for pure bitumen, bitumen-5%PVC, bitumen-7%PVC and bitumen-11%PVC, respectively. Because the bitumen softens and flow at high temperatures and its properties change considerably with temperature unlike the bitumen blends. That is more clear in Figure 3 for the complex viscosity, η^* of neat bitumen and bitumen-5%PVC at T_0 10 and 60°C . at ω~0.01 rad/s (T_0 10°C) the values of $\eta^*$are 10^1 , and 10^5 Pa.s for pure bitumen and bitumen-5%PVC, respectively.

4. CONCLUSION

Bitumen blends are prepared by the introduction of waste PVC up to a level of 11wt% in the molten state. The viscoelastic properties such as torque and viscosity of bitumen blends and neat bitumen are determined. These properties were studied using an ARES- Rheometer (Rheometric Scientific, Co.) equipment. The measurements were performed in the dynamic mode, plate-plate geometry of 25 mm diameter over the temperature range from –10 to 60°C and angular frequency, ω varied from 10^2 to10^{-1} radian/s. The results are compared at T_0 10 and 60°C over a wide range of ω . The results evidence that the incorporation of the waste PVC into bitumen enhances the torque and the viscosity. So, the stability of the bitumen composites is more noticeable at 60°C.

5. ACKNOWLEDGMENTS

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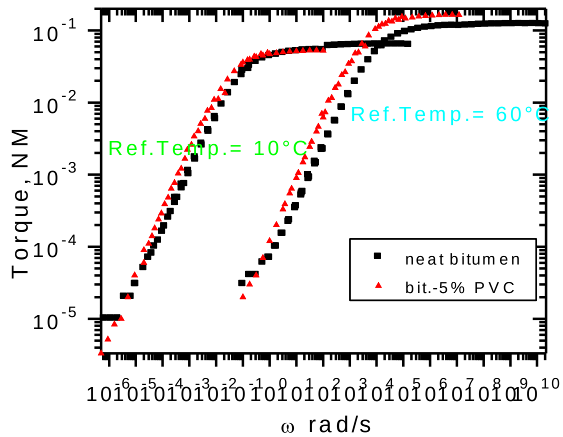

Figure 1: Master curves of torque for bitumen and bitumen blends as a function of ω at T_0=10 and 60

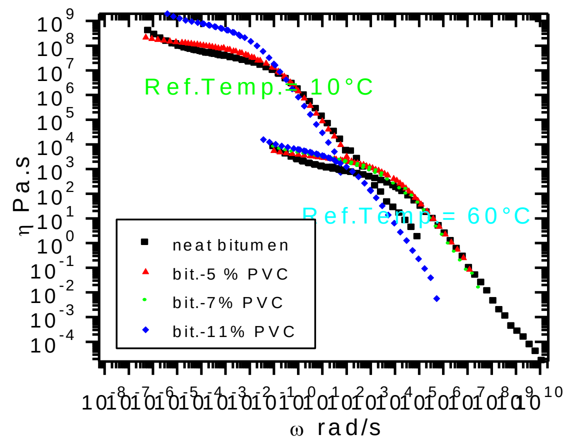

Figure 2: Master curves of ή for bitumen and bitumen blends as a function of ω at T_0=10 and 60°C

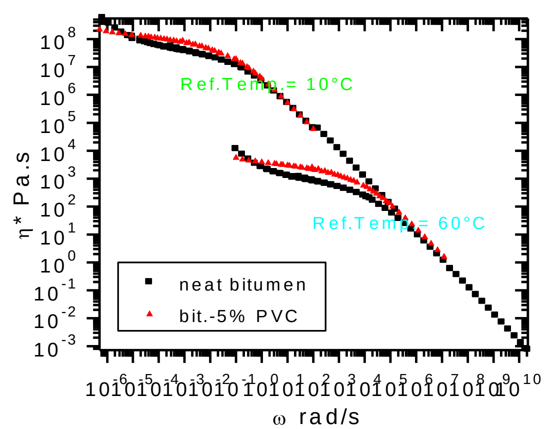

Figure 5: Master curves of η for bitumen and bitumen blends as a function of ω at T_0=10 and 60°C*