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The Effect of Styrene-Butadiene-Rubber (SBR) Polymer Modifier on Properties of Bitumen

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***Abstract*—**In order to use bitumen in hot mix asphalt, it must have specific characteristics. There are some methods to reach these properties. Using polymer modifiers are one of the methods to modify the bitumen properties. In this paper the effect of Styrene-Butadiene-Rubber that is one of the bitumen polymer modifiers on rheology properties of bitumen is studied. In this regard, the rheological properties of base bitumen and the modified bitumen with 3, 4, and 5 percent of Styrene-Butadiene-Rubber (SBR) were analysed. The results show that bitumen modified with 5 percent of SBR has the best performance than the other samples.

***Keywords*—**Bitumen, polymer modifier, styrene-butadiene-rubber, rheological properties.

I. Introduction

IN order to have an acceptable bitumen to making hot mix asphalt, it must have some specified characteristics. To have suitable bitumen that can be used to making HMA there are many methods to modify and improve the properties of it. One of these methods is using polymer modifiers such as SBS, PPA, SBR and etc. Each modifier changes some of properties of the base bitumen.

One of the polymer modifiers is Styrene-Butadiene-Rubber (SBR). There are some studies about the effect of this modifier on bitumen. Khadivar and Kavussi worked on rheological characteristics of SBR and NR polymer modified bitumen emulsions at average pavement temperatures. In this research the effects of SBR and NR polymers on characteristics of various bitumen emulsion binders were analyzed. Binders were tested applying fundamental and rheological bitumen tests. Temperature sweep and Multiple Stress Creep and Recovery testing were performed to characterize the rheological properties in linear and non-linear modes. In linear region, the presence of polymers improved stiffness and elastic properties of residual binders of the bitumen emulsions appreciably. Comparing the behavior of the two polymers in non-linear region resulted that SBR was more sensitive to applied stresses. Additionally, NR latex increased stiffness values of the emulsion residues substantially; while; their elastic properties were remained unchanged [1]. Zhang and Hu (2013) evaluate the properties of modified bitumen by SBR and SBS combine [2]. Zhang and et al evaluate the improved properties of SBR/weathered coal modified bitumen containing carbon black [3]. Zhang and Yu worked on high-performance SBR compound modified asphalt. This research shows that high-performance SBR compound modified asphalt can be made with the addition of polyphosphoric acid (PPA), styrene–butadiene rubber (SBR) and sulfur. The effects of PPA, SBR, and sulfur on the physical properties, the dynamic rheological properties, the high-temperature storage stabilities, the morphologies and the internal structures of asphalts were studied, respectively. The high-temperature storage stability of SBR-modified asphalt can be improved significantly with the addition of PPA and sulfur by the gelation effect and the dynamical vulcanization. The addition of SBR to the pure PPA modified asphalt improved the low-temperature physical properties with unfavorable effects on the resistance to rutting. The addition of sulfur to the PPA/SBR-modified asphalt improved the rheological properties and the adhesion of modified binders to stone matrix. The optimal proportion of PPA, SBR, and sulfur can improve the properties of asphalt roundly [4]. Yildirim worked on polymer modified asphalt binders. According to this paper polymer modification of asphalt binders has increasingly become the norm in designing optimally performing pavements, particularly in the United States, Canada, Europe and Australia. Specific polymers that have been used include rubber, SBR, SBS and Elvaloy®. Specifications have been designed and pre-existing ones modified to capture the rheological properties of polymer modified binders. The elastic recovery test is good at determining the presence of polymers in an asphalt binder, but is less successful at predicting field performance of the pavement [5].

In this paper the effect of SBR on complex modulus and phase angle are evaluated.

II. Material And Methods

In order to evaluate the effect of Styrene-Butadiene-Rubber on bitumen as a modifier 3, 4 and 5 percent of this polymer was mixed with the base bitumen. After that the dynamic mechanical analysis was conducted and the results are presented.

Dynamic mechanical analysis (DMA) was performed using a strain-controlled rheometer (RDA II, Rheometrics). In DMA, frequency sweeps were applied over the range of 0.1–100 rad/s at fixed strain amplitude at five temperatures: 25, 30, 40, 50, and 60◦C, and temperature sweeps (from 30 to 138◦C) with 2◦C increments were applied at a fixed frequency (10 rad/s) and at variable strains. High-temperature repeated creep tests were performed at 60 ◦C using a 1 s loading cycle followed by a recovery period of 9 s, and this was repeated 100 times. The repeated creep tests were made at a constant stress level of 30 Pa [6]. Parallel plates, gap 1.0 mm for ϕ25

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mm, were used. In each test, about 1.0 g of sample was applied to the bottom plate, covering the entire surface, and the plate was then mounted in the rheometer. After heating to the softening point of the binder, the top plate was brought into contact with the sample, and the sample was trimmed. The final gap was adjusted to 1 mm. A sinusoidal strain was then applied by an actuator. The actual strain and torque were measured and input to a computer for calculating various viscoelastic parameters such as complex modulus (G*) and phase angle (δ) and so on.

III. Results

In Fig. 1 the result of complex modulus of the base bitumen and modified ones are shown. According to this figure the complex modulus increased more by using 5% SBR modifier. For further investigation in Fig. 2 the ratio of complex modulus of modified bitumen to base bitumen are shown. According to this figure 5% SBR in all temperatures from 20°C to 80°C will more increase the complex modulus than 3% and 4% SBR. Also From 20°C to 40°C 3% and 4% SBR approximately have same effects on G^* and for temperatures above 40°C 5% SBR has better effects on bitumen. According to this graphs the modified bitumen will have a better interaction in traffic loading.

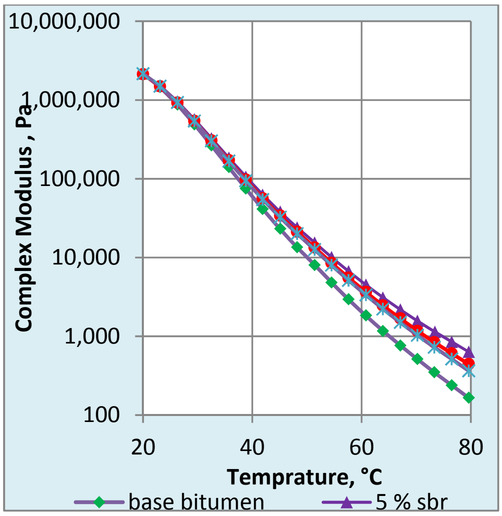

Fig. 1 Complex modulus of base bitumen and modified ones by using SBR

In Fig. 3 the result of phase angle of the base bitumen and modified ones are shown. According to this figure the phase angle decreased more by using 5% SBR modifier. For further investigation in Fig. 2 the ratio of phase angle of modified bitumen to base bitumen are shown. According to this figure 5% SBR in all temperatures from 20°C to 80°C decrease the phase angle more than 3% and 4% SBR.

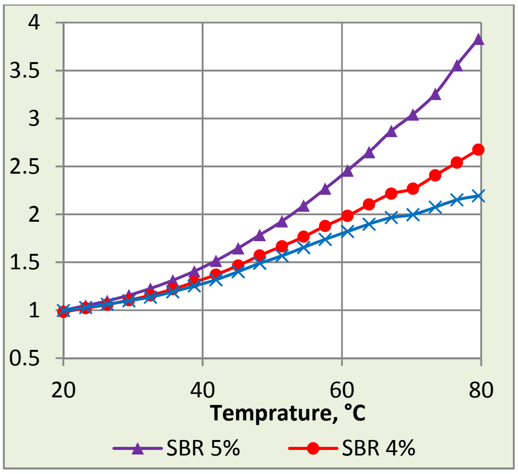

Fig. 2 Ratio of complex modulus of modified bitumen to base bitumen in different temperatures

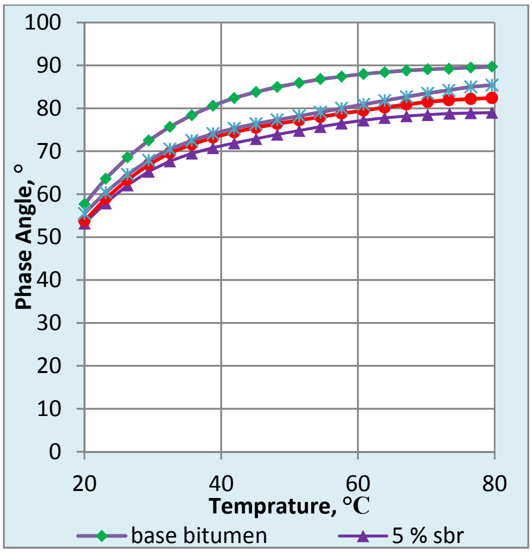

Fig. 3 Phase angle of base bitumen and modified ones by using SBR

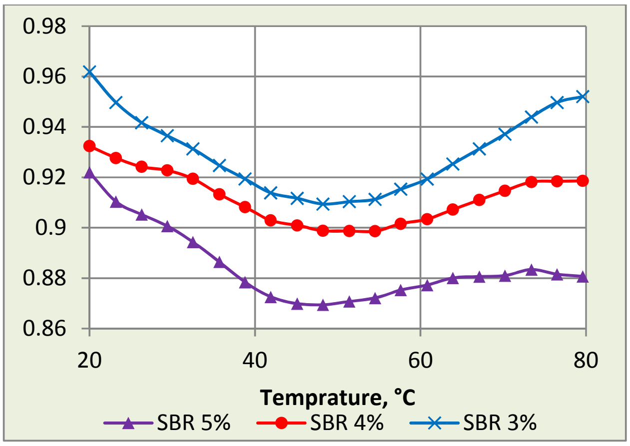

Fig. 4 Ratio of phase angle of modified bitumen to base bitumen in different temperatures

Fig. 5 shows that $|G^*| \cdot sin(\delta)$ increased after modification of the bitumen. Add 5 percent of SBR increased this factor more than other percentages of this modifier. Also in Fig. 6 ratio of $|G^*|\cdot sin(\delta)$ in modified bitumen to base bitumen for each percent of modifier are shown. As this figure shows for temperature more than 40°C, 5 percent of SBR will have best results of increasing $|G^*|\cdot sin(\delta)$ of bitumen. Thus modified bitumen with SBR will increase strength of asphalt against the fatigue cracking; and 5 percent of SBR will have the best result that 3 and 4 percent.

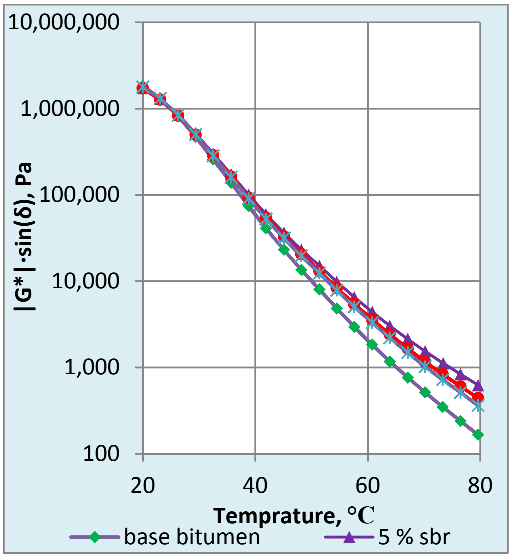

Fig. 5 $|G^*|\cdot sin(\delta)$ of base bitumen and modified ones by using SBR

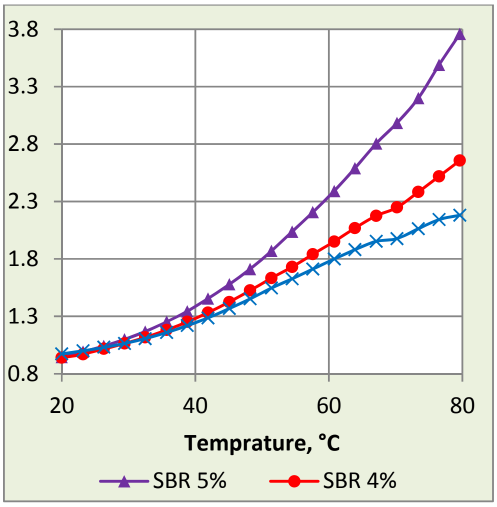

Fig. 6 Ratio of $|G^*|\cdot sin(\delta)$ of modified bitumen to base bitumen in different temperatures

Figs. 7 and 8 show the variation of $|G^*|/sin(\delta)$ with temperature change. As these figure shows, this parameter is increased after modifying bitumen with SBR. Also 5 percent of SBR will the best effects on bitumen properties in higher temperature rather than the other percentages of this polymer. Considering that changes in resistance of asphalt against rutting is related to $|G^*|/sin(\delta)$, as Figs. 7 and 8 show, the bitumen modified with 5 percent of SBR will have the best performance against this distress.

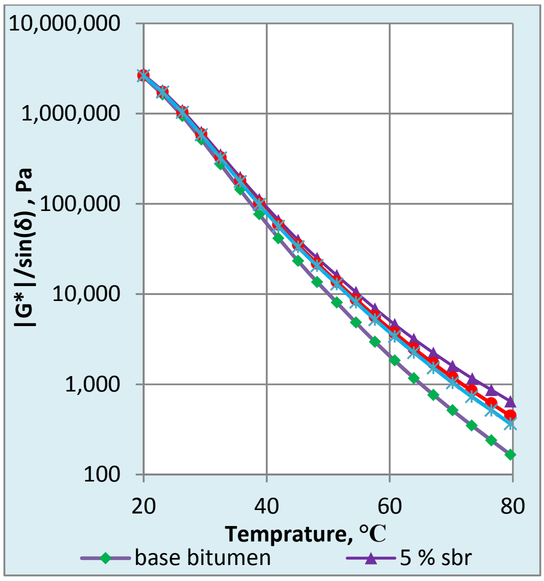

Fig. 7 $|G^*|/sin(\delta)$ of base bitumen and modified ones by using SBR

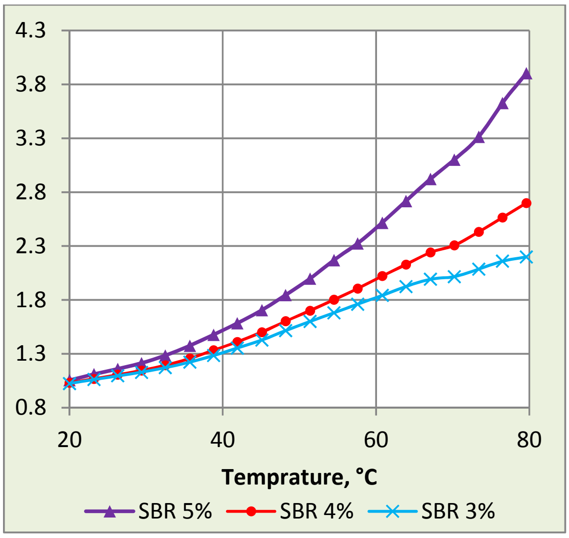

Fig. 8 Ratio of $|G^*|/sin(\delta)$ of modified bitumen to base bitumen in different temperatures

IV. Conclusion

According to this research by using SBR as bitumen modifier the complex modulus and phase angle have better values than base bitumen. Also $|G^*|\cdot sin(\delta)$ and $|G^*|/sin(\delta)$ will have better results in modified bitumen than unmodified one. Considering results5 percent of SBR as bitumen modifier will increase the performance of bitumen more than 3 and 4 percent of this polymer modifier. In higher temperature than 40°C the bitumen modified with 5 percent of SBR has better results for all parameters include Complex modulus, phase angle, $|G^*|\cdot sin(\delta)$ and $|G^*|/sin(\delta)$. But for temperature lower 40°C in all three cases the changes were same. As the results show, modified bitumen with SBR will have better performance against some distresses such as rutting and fatigue cracking and also the modified bitumen has greater complex modulus than base bitumen.

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