Comparative Evaluation of Mechanical Parameters of Bitumen Modified with SBR and LDPE Polymers Produced in Iran and Imported SBS Polymer

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ABSTRACT

Increase in traffic volume accompanied with increase in axle load will induce higher stresses in pavement structures as a result early failure of asphalt surface layer of pavement structures are observed. In the past two decades, modification of bitumen with polymeric materials has become a common practice to improve bitumen resistance against rutting and fatigue cracking. In this study SBS, SBR and LDPE are used with Sasobit as a catalyst substance to evaluate fatigue characteristics of bitumen modified with these polymeric materials. Common tests recommended by SHRP researchers for evaluation and classification of neat bitumen as well as the Linear Amplitude Sweep (LAS) test suggested for modified binders are conducted in this study. Dynamic Shear Rheometer (DSR) test results indicate that modification of neat bitumen with SBS, SBR and LDPE polymers improve rutting index and increase high performance temperature of binders by three levels. Also, sasobit reduces rotational viscosity of polymer modified binders and increases high performance temperature of SBS modified binder by one level. In addition, Results of the BBR test show that these additives do not have positive effect upon low performance temperature of the modified binders. A comparison of fatigue performance of polymer modified binders based on the LAS test results also showed that SBR polymer had the most effect on increasing fatigue life of the base binder. Besides, Sasobit increases the fatigue life of polymer modified binders at high strain levels.

KEYWORDS

binder, polymer additives, performance graded, binder fatigue, Linear Amplitude Sweep test

1. Introduction

Fatigue cracking and rutting are two of the most important failures caused by repeated loading in asphalt pavements [1]. Since that asphalt binders play an important role in the performance of asphalt mixtures, many studies have focused on evaluating the rheological properties of asphalt binders and improving their performance using various additives [2]. Polymer

modified binders are one of the common methods to achieve this goal.

Styrene butadiene styrene (SBS) is one of the most important polymer modifiers which is widely used in asphalt industry. Along with many benefits, the disadvantage of SBS is its thermal instability and thermal oxidation at high temperatures which reduces life span of asphalt pavement[3]. Besides, high price of SBS is comparable to other polymer additives, such as styrene butadiene rubber (SBR) and low-density polyethylene (LDPE). Therefore, SBR and LDPE, which are cost-effective additives and produced in local companies are used in this study to evaluate their efficiency compared to SBS polymer.

The main purpose of this study is to investigate the effect of SBS, SBR and LDPE polymer modifiers on the rheological properties of bitumen. In this study, in addition to the conventional superpave tests, additional test (PG^{+}) that introduced by FHW have also been used. Furthermore, the effect of sasobit on the characteristics of polymer modified binders has been investigated. In order to evaluate the fatigue behavior of asphalt binders, linear amplitude sweep (LAS) test has been performed.

2. Methodology and Testing

2.1. Bitumen Modification

In this study, the neat 85/100 penetration Bitumen of Jey Oil refinery, Isfahan, Iran was used as a base binder. According to previous studies, 6.5% SBS, 7.5% SBR and 7.5% LDPE was used to prepare polymer modified binders. Also, to reduce the viscosity of polymer modified binders, 2.5% sasobit has been used.

2.2. Testing Program

In this study, the rotational viscometer (RV) test, dynamic shear rheometer (DSR) test, bending beam rheometer (BBR) test and linear amplitude sweep (LAS) test were performed. The RV test was performed at temperatures of 135 °C (standard test temperature) in accordance with AASHTO T316 [4]. Also the DSR test was performed according to AASHTO T315 at frequency of 10 rad/s [5]. LAS tests were performed on PAV-aged binders at 25°C in accordance with AASHTO TP101 [6]. The validation of this test has been proven by many researchers to evaluate the performance of the binder against fatigue cracking [7]. Analysis of LAS test results are performed using viscoelastic continuum damage (VECD) theory. The fatigue life of asphalt binders is also calculated by equation (1).

$$N_f = A\left(\gamma_{\max}\right)^{-B} \quad (1)$$

3. Results and Discussion

3.1. Performance graded of asphalt binders

"Figure 1" and "Figure 2" show the effect of additives on PG upper temperature of asphalt binders. As show, high temperature performance of neat bitumen has increased for both un-aged and RTFO-aged binder. By the addition of 7.5% LDPE, PG upper temperature of neat bitumen for un-aged binder, has risen from 58 °C to 82 °C. Also, SBS and SBR modified binders, satisfied superpave requirements at 76 °C. In addition, Sasobit leads to an increase in the $G^{*}/\sin\delta$ parameter, resulting in improved polymer modified binders at high temperatures.

Based on the results of superpave tests, performance graded of asphalt binders are shown in table 1. Polymer additives improved high temperature performance of base binder by three grade. Also, 2.5% sasobit was able to increase PG upper temperature SBS modified binder by one grade. However, sasobit did not have a positive effect on the low temperature performance of polymer modified binders.

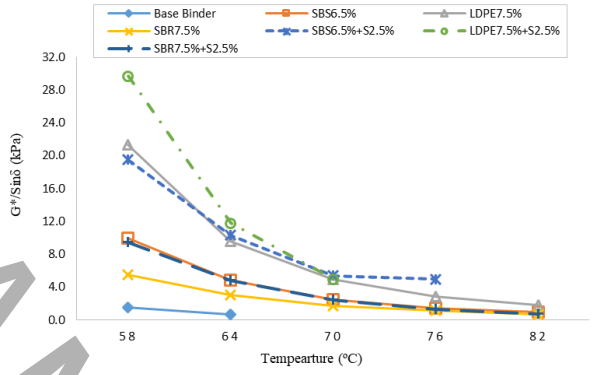

Fig. 1. Rutting parameter for un-aged binders

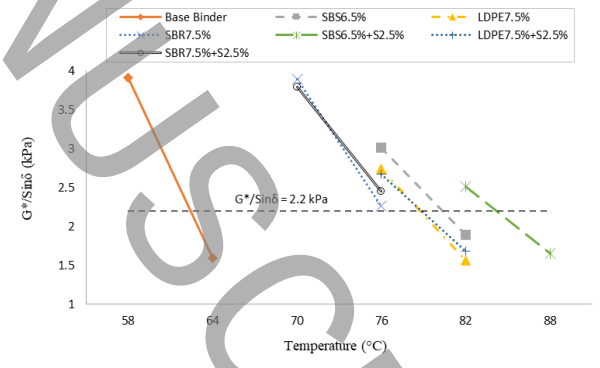

Fig. 2. Rutting parameter for RTFO-aged binders

Table 1. Performance grade for asphalt binders

Binder sample	PG
Base binder	PG 58-22
6.5% SBS	PG 76-16
7.5% LDPE	PG 76-10

7.5% SBR	PG 76-10
6.5% SBS + 2.5% S	PG82-10
7.5% LDPE + 2.5% S	PG 76-10
7.5% SBR + 2.5% S	PG 76-10

Table 2. VECD analysis parameters

Binder sample	A parameter	B parameter
Base binder	2.15×10^5	3.22
6.5% SBS	8.79×10^5	4.30
7.5% LDPE	7.15×10^5	4.29
7.5% SBR	6.4×10^5	3.87
6.5% SBS + 2.5% S	4.84×10^5	4.02
7.5% LDPE + 2.5% S	9.7×10^5	4.68
7.5% SBR + 2.5% S	3.55×10^5	3.41

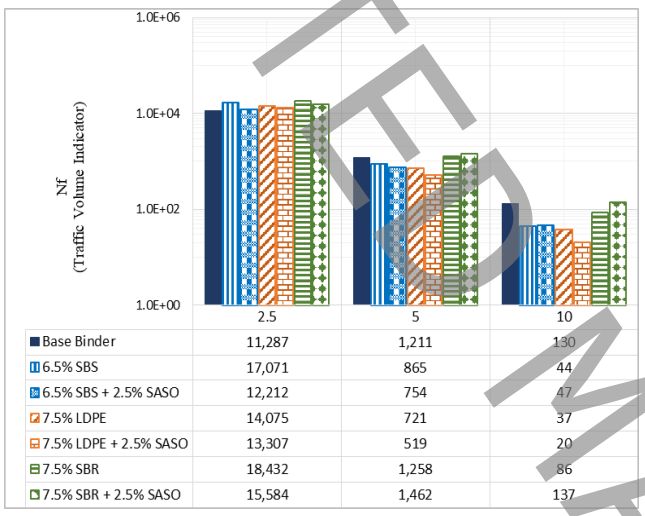

Fig. 3. Fatigue lives of asphalt binders

3.2. LAS test results

The value of parameters of A and B are shown in table 2. Also, fatigue lives of asphalt binders, which was calculated using equation (1) at strain levels of 2.5%, 5% and 10%, are presented in "Figure 3". At strain level of 2.5% and compared to the base binder, fatigue life of asphalt binders modified with SBS, LDPE and SBR increased by 51%, 25% and 63%, respectively. Binder samples containing 7.5% SBR have the highest fatigue life at strain levels of 2.5% and 5%.

Effect of sasobit on the fatigue performance of polymer modified binders is also significant. At low strain levels sasobit reduced the fatigue life of asphalt binders containing SBS, LDPE and SBR by 28%, 6% and 16%, respectively. However, as shown in "Figure 3" at high strain levels, sasobit increased fatigue life of asphalt binders modified with SBS and SBR.

4. Conclusions

The main objectives of this study are as follows:

- Polymer additives increase rutting resistance of base binder. The highest value of rutting parameter related to binder sample modified with 7.5% LDPE.
- Polymer additives have no positive effect on low temperature performance of base binder.
- Fatigue life of asphalt binders increased at low strain level compared to the base binder. The highest fatigue life was related to binder containing 7.5% SBR, which increased by 63% compared to the base binder.
- Sasobit improves high temperature performance of polymer modified binders.
- Effect of sasobit on fatigue performance of asphalt binders at various strain levels has been different.
- Comparison of the performance of polymer additives used in this study shows that in term of high temperature performance, LDPE polymer modified binder has better performance than SBS polymer. Besides, fatigue performance of SBR modified binder has been better compared to SBS polymer at both low and high strain levels. Therefore, the use of SBR and LDPE polymers instead of SBS polymer is both economical and a good option for improving performance characteristics of asphalt binders.

5. References

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