Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(8) (2021) 747-750
DOI: 10.22060/ceej.2020.17919.6711

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

M. Ameri* , A. H. Ameri, E. Riahi, A. Afshin

School of Civil Engineering, Iran University of Science and Technology, Tehran, Iran

ABSTRACT: An increase in traffic volume accompanied by an increase in axle load will induce higher stresses in pavement structures as a result early failure of the asphalt surface layer of pavement structures is 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 indicated that modification of neat bitumen with SBS, SBR, and LDPE polymers improved rutting index and increases high performance temperature of binders by three levels. Also, Sasobit reduced the rotational viscosity of polymer-modified binders and increased the high performance temperature of SBS-modified binders by one level. In addition, results of the BBR test showed that these additives did not have a positive effect upon the 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 the fatigue life of the base binder. Besides, Sasobit increased the fatigue life of polymer-modified binders at high strain levels.

Review History:
Received: Feb. 13, 2020
Revised: May. 18, 2020-0
Accepted: Jun. 03, 2020
Available Online: Jun. 29, 2020

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 the asphalt industry. Along with many benefits, the disadvantage of SBS is its thermal instability and thermal oxidation at high temperatures which reduces the life span of asphalt pavement[3]. Besides, the 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. To evaluate the fatigue behavior of asphalt binders, a linear amplitude sweep (LAS) test was performed.

*Corresponding author's email: ameri@iust.ac.ir

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 were used to prepare polymer-modified binders. Also, to reduce the viscosity of polymer-modified binders, 2.5% Sasobit was used.

2.2. Testing program

In this study, the rotational viscometer (RV), dynamic shear rheometer (DSR), bending beam rheometer (BBR), and linear amplitude sweep (LAS) tests 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 a 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

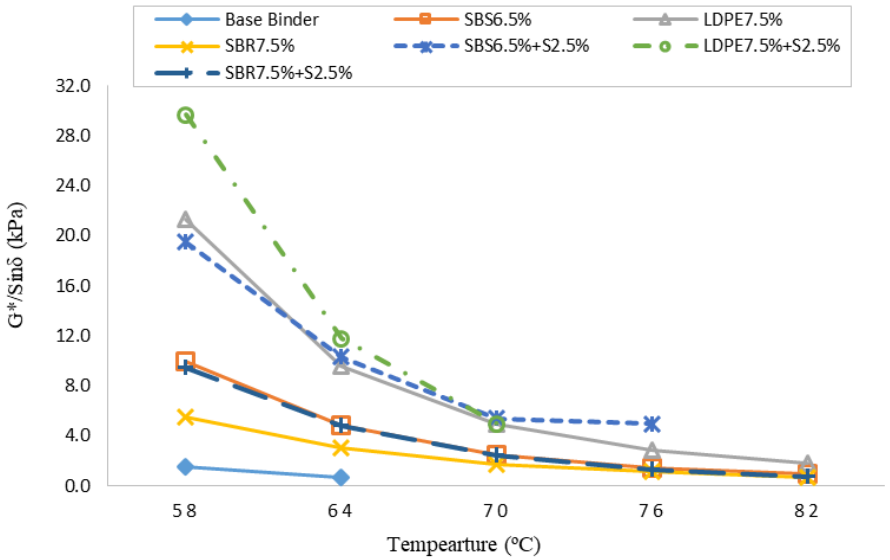

Fig. 1. Rutting parameter for un-aged binders

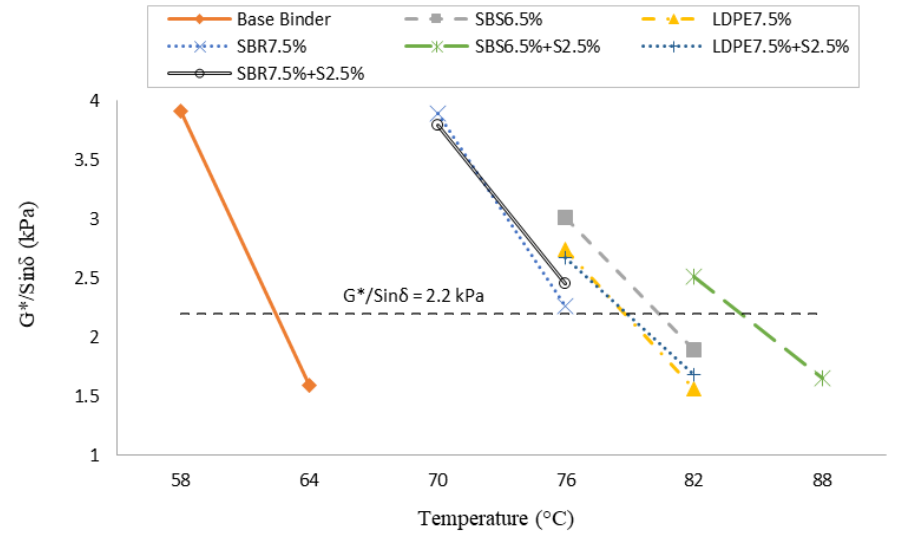

Fig. 2. Rutting parameter for RTFO-aged binders

many researchers to evaluate the performance of the binder against fatigue cracking [7]. Analysis of LAS test results was performed using viscoelastic continuum damage (VECD) theory. The fatigue life of asphalt binders is also calculated by Eq. (1).

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

3. RESULTS AND DISCUSSION

3.1. Performance graded of asphalt binders

Figs. 1 and 2 show the effect of additives on PG upper temperature of asphalt binders. As can be seen, the high-temperature performance of neat bitumen has increased for both un-aged and RTFO-aged binders. With the addition of 7.5% LDPE, the 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 $G^*/\sin d$ parameter, resulting in improved polymer modified binders at high temperatures.

Based on the results of Superpave tests, performance grades of asphalt binders are shown in Table 1. Polymer additives improved the high-temperature performance of the base binder by three grades. 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.

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 were calculated using Eq. (1) at strain levels of 2.5, 5, and 10%, are presented

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

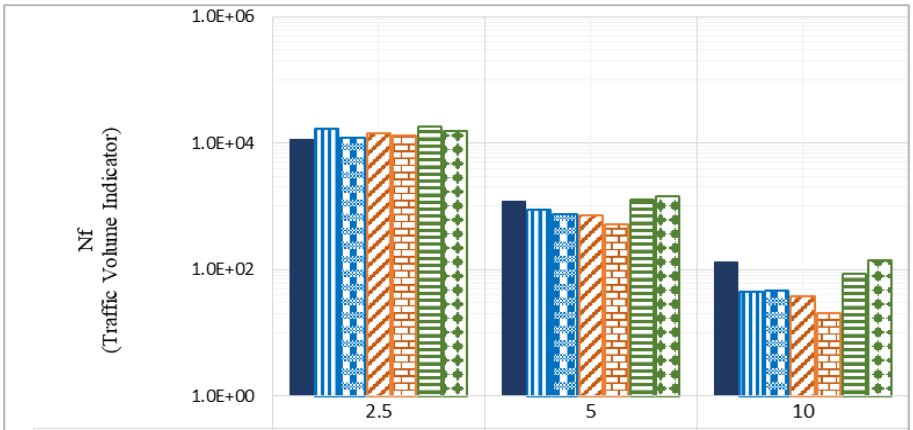

Fig. 3. Fatigue lives of asphalt binders

in "Fig. 3". At a strain level of 2.5% and compared to the base binder, the 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%.

The 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 "Fig. 3" at high strain levels, Sasobit increased fatigue life of asphalt binders modified with SBS and SBR.

4. CONCLUSION

The main objectives of this study are as follows:

· Polymer additives increased the rutting resistance of the base binder. The highest value of rutting parameter was related to binder sample modified with 7.5% LDPE.

· Polymer additives had no positive effect on the low-temperature performance of the base binder.

· The fatigue life of asphalt binders increased at a 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 improved the high-temperature performance of polymer-modified binders.

· The effect of Sasobit on fatigue performance of asphalt binders at various strain levels had been different.

· Comparison of the performance of polymer additives used in this study showed that in terms of high-temperature performance, LDPE polymer modified binder had better performance than SBS polymer. Besides, fatigue performance of SBR modified binder had 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 was both economical and a good option for improving the performance characteristics of asphalt binders.

REFERENCES

[1] M. Ameri, D. Mirzaiyan, A. Amini, Rutting resistance and fatigue behavior of gilsonite-modified asphalt binders, J. Mater. Civ. Eng., 30 (2018) 1–9.
[2] M. Porto, P. Caputo, V. Loise, S. Eskandarsefat, B. Teltayev, C.O. Rossi, Bitumen and bitumen modification: A review on latest advances, Appl. Sci., 9 (2019) 1–35.
[3] M. Ameri, M. Vamegh, R. Imaninasab, H. Rooholamini, Effect of nanoclay on performance of neat and SBS-modified bitumen and HMA, Pet. Sci. Technol., 34 (2016) 1091–1097.
[4] AASHTO, Standard method of test for viscosity determination of asphalt binder using rotational viscometer, 2010.
[5] AASHTO T315, Standard Method of Test for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR), American Association of State and Highway Transportation Officials, (2012).
[6] AASHTO, Standard method of test for estimating damage tolerance of asphalt binders using the linear amplitude sweep, 2012.
[7] C. Hintz, R. Velasquez, C. Johnson, H. Bahia, Modification and validation of linear amplitude sweep test for binder fatigue specification, Transp. Res. Rec., 2207 (2011) 99–106.

HOW TO CITE THIS ARTICLE

M. Ameri, A.H. Ameri, E. Riahi, A. Afshin, Comparative Evaluation of Mechanical Parameters of Bitumen Modified with SBR and LDPE Polymers Produced in Iran and Imported SBS Polymer, Amirkabir J. Civil Eng., 53(8) (2021) 747-750.

DOI: 10.22060/ceej.2020.17919.6711