The Performance of SBS Modified asphalt binder base on the MSCR Test

Jianping Xiong¹, Weian Xuan¹, Mingzhu Feng¹ and Feng Ma²*

¹Guangxi Transportation Research Institute, Guangxi Key Lab of Road Structure and Material, Nanning, China
²Key Laboratory for Special Area Highway Engineering of Ministry of Education, Chang’an University, Xi’an, China
*Corresponding author e-mail: 250888913@qq.com

Abstract. SBS modified asphalt has been generally used to improve the high temperature performance of asphalt pavement in past decades. This research work evaluated the effect of SBS on high temperature performance of asphalt binder in ways of Multiple Stress Creep Recovery (MSCR). The penetration, softening point and MSCR test were conducted in order to come to conclusions regarding high temperature rutting performance of SBS modified asphalt binders. The amount of SBS was varied as 3%, 4% and 5% by the weight of the base binder. Based on \( J_{nr} \) and \( R\% \), addition of SBS to the base asphalt binder help in significantly improving the rutting resistivity potential.

1. Introduction
There are over ninety percent of paved freeways which are surfaced with asphalt in China. There is a widespread recognition that binder play an important role in the behavior of asphalt concrete and performance of asphalt pavement. Asphalt binder, as one of the load carrying components of the asphalt mixture, is a viscoelastic and thermoplastic material. The property of asphalt binder is usually characterized by a certain level of rigidity of an elastic solid body. Asphalt binder is responsible for the viscoelastic behavior or asphalt mixture. Asphalt binder is a premium role in overall pavement performance such as resistance to permanent deformation, or rutting.

Processes of asphalt modification involving natural and synthetic polymers were patented as early as 1843. In 1950s, in order to get greater interest in decreased life cycle costs, Europe contractors were ahead in the use of modified asphalt. In the middle of 1980s, newer polymers were developed and European technologies began to be used in the USA [1]. It is found that the modified binders were more resistant to both fatigue and rutting than the base binder. In order to improve the performance and durability of roads in China, the SBS modified asphalt is popularly used in the top layer and the second layer of the asphalt pavement.

The SHRP specifications of asphalt binder developed in 1992 have a positive influence worldwide. The rutting parameter \( (G^*/\sin \delta) \) is used in the high temperature performance grading of a binder, particularly in rating the binder for rutting resistance. The rutting parameter was found to be inadequate in describing the rutting performance of certain binders, particularly polymer modified binders. The Repeated Creep Recovery Test (RCRT) method was proposed to estimate the rate of accumulation of permanent strain in the binder. On the base of RCRT test protocol, D’Angelo et al.
improved the Multiple Stress Creep Recovery (MSCR) test by running creep and recovery testing on one sample at multiple stress levels [2, 3]. The new parameter called non-recoverable compliance \( J_{nr} \). And \( J_{nr} \) is considered be both performance-based and be applied to both base asphalt binder and polymer modified asphalt binder [4, 5].

The performance of a penetration grade 90# base asphalt and SBS modified binder is evaluated in this paper. The penetration and softening point, ductility and MSCR test were conducted in this research.

2. Materials and Test Methods

A suite of asphalt binder characterization test were conducted to evaluate the high temperature performance of a penetration grade 90# base asphalt and SBS modified binder. The modified asphalt binders were prepared with 3%, 4% and 5% SBS in mass respectively. The penetration and softening point, ductility and MSCR test were conducted in this research. The property of the base binder is shown in Table 1.

| Base asphalt | 25℃ Penetration (100g, 5s) | Softening point (°C) | 5℃ Ductility (cm) |
|--------------|--------------------------|---------------------|-----------------|
| P-90#        | 81.4                     | 45.6                | 5.54            |

A DHR-1 Dynamic Shear Rheometer (DSR) with a 25-mm parallel plate geometry set-up was employed in this study. The MSCR test is a creep and recovery test that uses a load for 1 second followed by a 9 second recovery period in each cycle. During the 9-second rest period, the specimen recovers a portion of the strain that is developed in 1 second loading period. Following the ASSHTO TP70 method, two stress levels, 0.1 kPa and 3.2 kPa, are used with the application of a controlled shear stress. And The procedure is applied a 0.1 kPa shear stress for 10 consecutive creep-recovery and immediately follow by another 10 cycles of a 3.2 kPa shear stress. The MSCR test protocol is illustrated in Figure 1. For the each cycle, the first 1 second is the creep procedure, and the consecutive 9-second is the recovery procedure. The elastic property is shown by the recovery strain, and at the same time the viscose property is shown by the non-recovery strain.

The non-recoverable creep compliances \( J_{nr} \) and percent recoveries \( R\% \) were computed at each stress levels and temperatures to characterize the stress dependency and temperature sensitivity of polymer-modified binders. For a particular stress cycle, \( J_{nr} \) is computed by dividing the non-

![Figure 1. MSCR test protocol](image-url)
recoverable strain with the stress applied for that cycle. Therefore, \( J_{nr} \) for a particular loading cycle is shown in Equation 1. The percent recovery for a particular loading cycle is shown in Equation 2.

\[
J_{nr} = \frac{\gamma_{nr}}{\sigma} = \frac{\varepsilon_{r,10} - \varepsilon_{0,1}}{\sigma} \tag{1}
\]

\[
R\% = \left( \frac{\varepsilon_{c,1} - \varepsilon_{0,1}}{\varepsilon_{c,1} - \varepsilon_{0,10}} \right) \tag{2}
\]

Where: 
\( \varepsilon_{r,10} \), stain in the end of the recovery stage
\( \varepsilon_{0,1} \), initial strain in the creep stage
\( \varepsilon_{c,1} \), stain in the end of the creep stage

\( J_{nr} \) is a measure of the binder’s contribution to mixture permanent deformation behavior. And \( R\% \) reflects the elasticity of asphalt binder. The testing temperature is 60°C. Three replicates are used for each type of binder.

3. Results and discussions

The penetration test is conducted on 25°C. The result is shown in the Figure 1. The softening point of the base binder and SBS modified asphalt is shown in Figure 2. And the ductility of base binder and SBS modified asphalt binder is shown in Figure 3.

As shown these figures, adding the SBS into asphalt can decrease the 25°C penetration obviously. The softening point increase slightly with addition of the SBS. The ductility has an obvious improvement with the SBS modifier. 5% SBS modified asphalt has a good performance. And there are 33%, 68% and 445% increase in 25°C penetration, softening point and 5°C ductility respectively. It shows the addition of SBS can improve high temperature and crack resistance performance. And the more SBS modifier, the total performance is better.

The MSCR test is conducted at 56°C on virgin binder at stress levels of 0.1 kPa and 3.2 kPa. The MSCR test results of base asphalt and SBS modified asphalt are shown in Figure 4 and 5.
For SK90 binder, $J_{nr}$ at 0.1kpa is 0.32. $J_{nr}$ at 0.1kpa of 3% and 5% SBS modifier binder are 0.08 and 0.04 respectively. The same trend is observed on $J_{nr}$ at 3.2kpa. It can be seen that $J_{nr}$ at both 0.1kpa and 3.2 kPa significantly decreased with the addition of SBS, showing improved rutting sensitivity potential. Although a decrease in $J_{nr}$ value is observed when the SBS content increased from 3% to 5% at stress level of 0.1 kPa, only smaller improvement in the $J_{nr}$ value is evident at a stress level of 3.2 kPa.

As shown in figure 4 and 5, an increase in $R\%$ can be observed for both stress levels. The addition of SBS resulted in improved recovery response, particularly at 0.1 kPa, indicating better rutting performance of binders. Further, the $R\%$ is higher than the corresponding value at the stress level of 3.2 kPa. The Recovery rate$\%$ for 5% SBS is 66.4% and 32.7% corresponding to stress levels of 0.1 kPa and 3.2 kPa, respectively. The SBS modifier improve the recovery response, it may also make the asphalt binder sensitive toward vehicular loading, especially during the rest period and unloading phase. Application of a higher stress level of 3.2 kPa leads the SBS modified asphalt binder to be sensitive to stress.

4. Conclusion
This research work evaluated the effect of SBS on high temperature performance of asphalt binder. The penetration, softening point and MSCR test were conducted in order to come to conclusions regarding high temperature rutting performance of SBS modified asphalt binders. The amount of SBS was varied as 3%, 4% and 5% by the weight of the base binder. The following conclusions can be drawn from the test results and discussion of this paper.

From penetration and softening point test result, adding the SBS modifier into base asphalt can increase softening point and can decrease the 25℃ penetration. The addition of SBS improves the high temperature of the asphalt binder.

Based on test results of $J_{nr}$ and $R\%$, adding the SBS into base asphalt can decrease $J_{nr}$ can increase $R\%$. The addition of SBS to the base asphalt binder help in significantly improving the rutting resistivity potential.

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