Evaluation of the Effect of Slack wax and Polypropylene wax on the Rutting Properties of Crumb Rubber Modified Binder

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ABSTRACT

The use of crumb rubber to modify the binders has been the interest of researchers for many years. It has been proven that the use of asphalt mixtures containing crumb rubber is leading to improve performance and increase the durability of asphalt pavement. However, increasing the viscosity of Crumb Rubber Modified (CRM) binder which increases mixing and compaction temperature of asphalt mixture, known as one of the disadvantages of using crumb rubber. So, there is a good concept for using warm mix additives to besides improving the performance of asphalt mixture, reduce energy consumption and environmental pollution also be considered. On the other hand, binder has an important role in investigation of the performance of the asphalt mixture. It is also time-consuming and costly to evaluate the properties of asphalt mixtures. Hence, evaluating the performance characteristics of the binder helps in understanding the performance of asphalt mixtures against various types of damage. The main objective of this study is to investigate the effect of organic warm mix additives (waxes) on the rutting performance of CRM binder by using the Multiple Creep Stress Recovery (MSCR) test. Because, it was found that the MSCR test results have a good correlation to rutting than SHRP criteria. The results of this study show that the use of polypropylene wax in addition to increase rutting resistance of CRM binder also will lead to increase in pavement traffic level by one degree. Despite of this, slack wax reduces rutting resistance of CRM binder by increasing the J_{nr} parameter.

KEYWORDS

binder rheology, warm mix additives, crumb rubber modified binder, rutting, Multiple Stress Creep Recovery test

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1. Introduction

Rutting is one of the most important failures that occur during the service life of asphalt pavements and significantly impacts its performance[1]. Among the asphalt components, Bitumen plays an important role in determining the viscoelastic behavior and performance of asphalt mixtures. The results of the researches show that the resistance of asphalt mixtures against rutting depends considerably on the rheological characteristics of Bitumen[2].

Researches results show that the use of crumb rubber results in longer service life, lower repair and maintenance costs, improve rutting resistance, lower road noise and increase skid resistance for asphalt pavement[3,4]. However, crumb rubber leads to an increase in the viscosity of modified binder. As a result, mixing and compaction temperature of asphalt mixtures containing crumb rubber increases[5]. So, asphalt mixtures containing crumb rubber have great potential for using warm mix asphalt technology. Different types of warm mix additives can significantly reduce the mixing and compaction temperature of CRM asphalt mixtures by reducing the viscosity of CRM binder and increasing its workability[6].

In recent years, the effect of warm mix additives on the rheological properties of bitumen modified with crumb rubber has been studied[7,8]. Research findings to date indicate that in some cases, warm mix additives can be used without adversely affecting the performance properties of CRM binder[9]. However, there are conflicting results in the performance of warm rubberized binder, mainly due to the effects of different types of warm mix additives.

The main purpose of this study is to investigate the effect of warm mix additives on the rutting performance of CRM binders. In Iran, the relatively high costs of supplying commonly available warm mix additives, which are mainly imported, are recognized as one of the problems. For this reason, Slack wax and Polypropylene wax, which are both native and inexpensive are used in this study.

2. Methodology and Testing

2.1. Bitumen Modification

In this study, the neat 60/70 penetration Bitumen of Iran Pasargad Oil Company was used as a base binder. Also, 15% crumb rubber with mesh size 40 was used to obtain CRM binder. Slack wax and Polypropylene wax were used at 2, 4 and 6 % by weight of the neat binder.

2.2. Testing Program

In this study, the rotational viscosity (RV) test, dynamic shear rheometer (DSR) test, and multiple stress recovery (MSCR) test were performed. The RV test was performed at temperatures of 135 (standard test temperature), 165 and 185 °C in accordance with AASHTO T316[10]. Also the DSR test was performed according to AASHTO T315 at frequency of 10 rad/s[11]. MSCR tests were performed on RTFO-aged binders at 64°C (neat binder high performance temperature) to simulate short term aging in accordance with AASHTO TP70 standard[12]. The validation of this test has been proven by many researchers to evaluate the performance of the binder at high temperature. Zhou et al. also showed that the parameters obtained from the MSCR test, especially for polymer modified binders, had better results than the SHRP parameter in ranking binders based on rutting criteria[13].

3. Results and Discussion

3.1. MSCR test results

"Figure 1" and "Figure 2" show the percent recovery (R%) and non-recoverable creep compliance (J_{nr}) values for asphalt binders. Polypropylene wax increased the amount of R parameter at both stress levels in general and thereby improved the rutting resistance of the CRM binder. The J_{nr} parameter is used to evaluate the resistance of binder to permanent deformation under the influence of repetitive loading. Lower values of J_{nr} indicate greater resistance to permanent deformation and better performance against rutting. By adding Slack wax to the CRM binder and increasing its percentage, the value of J_{nr} increases. Therefore, CRM binder containing Slack wax has less resistance to rutting. However, Polypropylene wax reduces the amount of J_{nr} compared to the CRM binder. The binder containing 2% Polypropylene wax has the highest resistance to rutting at both stress levels. The performance classification of binders based on traffic level as recommended by the AASHTO M332[14] are presented in "Table 1".

Table 1. Performance graded asphalt binders based on traffic level

Binder type	$J_{nr@3.2}$(kPa^{-1})	$J_{nr-diff}$%	Traffic Level
60-70	1.93	12.2	H
CR15	0.51	54.5	V
CR15S2	0.67	55.8	V
CR15S4	0.82	64	V
CR15S6	1.37	71.25	H
CR15P2	0.26	44.4	E
CR15P4	0.37	54.2	E
CR15P6	0.48	65.5	E

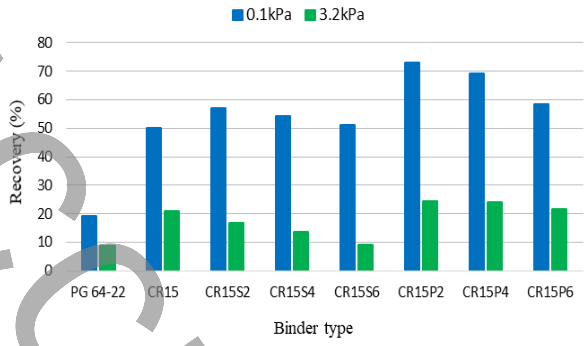

Figure 1. Recovery percentage of asphalt binders at 100 and 3200 Pa stress levels

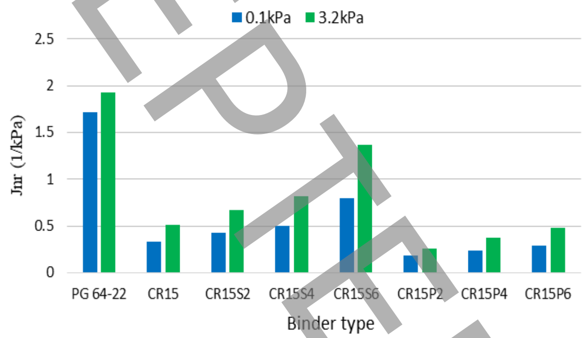

Figure 2. Non-recoverable creep compliance (Jnr) of asphalt binders at 100 and 3200 Pa stress levels

4. Conclusions

The main objectives of this paper are as follows:

- Slack wax and Polypropylene wax reduce the viscosity of the CRM binder. Thus, one of the disadvantages of CRM binders, which is the increase in viscosity and consequently the increase in the production and compaction temperature of asphalt mixture, is eliminated.

- 2% Polypropylene wax increases high-performance temperature of CRM binder by one degree.

- Polypropylene wax results in increased rutting resistance of CRM binder with increasing percent recovery and decreasing J_{nr}. Although Slack wax reduces rutting resistance of CRM binder.

- In terms of Performance Grading based on AASHTO M332 and in comparison with the CRM binder, Polypropylene wax leads to an increase in traffic level from V to E.

5. References

[1] Du, Y., Chen, J., Han, Z., and Liu, W., 2018.“A Review on Solutions for Improving Rutting Resistance of Asphalt Pavement and Test Methods,” *Construction and Building Materials*, 168, pp. 893–905.

[2] Radhakrishnan, V., Ramya Sri, M., and Sudhakar Reddy, K., 2018.“Evaluation of Asphalt Binder Rutting Parameters,” *Construction and Building Materials*, 173, pp. 298–307.

[3] Kaloush, K. E., 2014.“Asphalt Rubber : Performance Tests and Pavement Design Issues,” *Construction and Building Materials*, 67, pp. 258–264.

[4] Venudharan, V., and Biligiri, K. P., 2016.“Conceptualization of Permanent Deformation Characteristics of Rubber Modified Asphalt Binders: Energy-Based Algorithm and Rheological Modeling,” *Construction and Building Materials*, 126, pp. 388–397.

[5] Yu, H., Leng, Z., Dong, Z., Tan, Z., Guo, F., and Yan, J., 2018.“Workability and Mechanical Property Characterization of Asphalt Rubber Mixtures Modified with Various Warm Mix Asphalt Additives,” *Construction and Building Materials*, 175, pp. 392–401.

[6] Oliveira, J. R. M., Silva, H. M. R. D., Abreu, L. P. F., and Fernandes, S. R. M., 2013.“Use of a Warm Mix Asphalt Additive to Reduce the Production Temperatures and to Improve the Performance of Asphalt Rubber Mixtures,” *Journal of Cleaner Production*, 41, pp. 15–22.

[7] Akisetty, C., 2008.“Evaluation of Warm Asphalt Additives on Performance Properties of CRM Binders and Mixtures,” Clemson University.

[8] Yu, H., Leng, Z., Zhou, Z., Shih, K., and Xiao, F., 2017.“Optimization of Preparation Procedure of Liquid Warm Mix Additive Modi Fi Ed Asphalt Rubber,” *Journal of Cleaner Production*, 141, pp. 336–345.

[9] Wang, H., Liu, X., Apostolidis, P., and Scarpas, T., 2018.“Review of Warm Mix Rubberized Asphalt Concrete: Towards a Sustainable Paving Technology,” *Journal of Cleaner Production*, 177, pp. 302–314.

[10] 2010.“AASHTO Standard T316, Standard Method of Test for Viscosity Determination of Asphalt Binder Using Rotational Viscometer, American Assiciation of State and Highway Transportation Officials.”

[11] Subhy, A., 2017.“Advanced Analytical Techniques in Fatigue and Rutting Related Characterisations of Modified Bitumen: Literature Review,” *Construction and Building Materials*, 156, pp. 28–45.

[12] 2012.“AASHTO TP70, Standard Method of Test for Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR).”

[13] Zhou, F., Li, H., Chen, P., and Scullion, T., 2014.*Laboratory Evaluation of Asphalt Binder Rutting, Fracture, and Adhesion Tests.*, Texas. Dept. of Transportation. Research and Technology Implementation Office.

[14] 2014.“AASHTO M332, Standard Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test, Wshington.”