Evaluation of the long-term performance of naphthenic recycling agent in restoring the properties of aged bitumen

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ABSTRACT

Investigating the performance of bitumen restored by recycling agents in maintaining or destroying the properties and characteristics of bitumen in the next period of pavement service is completely limited. The aim of this research was to evaluate the immediate and long-term effect of a naphthenic recycling agent in restoring the properties of aged bitumen. In this research, bitumen separation and infrared spectroscopy experiments to investigate the chemical properties of bitumen samples, Penetration, Softening Point, Rotational Viscometer, Multiple Stress Creep Recovery, and Linear Amplitude Sweep were used to evaluate the physical and rheological properties of bitumen samples. To evaluate the long-term performance of the recycling agent, the restored bitumen was to long-term aged by aging simulation test. The results show that the use of naphthenic recycling agent in the optimal amount has restored the chemical, physical and rheological properties of aged bitumen to the base bitumen level. The naphthenic recycling agent results in a 38% reduction in the CI of aged bitumen, which indicates that the aged bitumen is softer and its colloidal structure is stable. It also reduces the rutting resistance of aged bitumen to the level of base bitumen. The limited increase in CI due to aging in restored bitumen indicates that the naphthenic recycling agent has performed well in maintaining the stability of the colloidal structure of bitumen in the long term. The results also show that the use of naphthenic recycling agent improves the fatigue performance of restored bitumen in the long term compared to base bitumen.

KEYWORDS

Aging, Long-term performance, Recycling agent, Rutting, Fatigue

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1. Introduction

Bitumen is exposed to various damages (such as aging) during the asphalt processing and paving service [1]. Bitumen aging is one of the most important problems related to the use of bitumen in road works [2]. Therefore, understanding the effect of bitumen aging in the design of asphalt mixtures is important to achieve proper longevity and durability [3]. During the aging process, the chemical properties of bitumen change, and the ratio of asphaltene to maltene increases. This change increases the viscosity and decreases the ductility of bitumen and the resistance of bitumen to thermal cracking, which reduces the durability of the pavement [4]. There are various methods to restore the properties of aged bitumen, such as the use of softer bitumen, recycling agents, polymers, etc. [5]. Haghshenas et al. [6] described the chemical properties of various recycling agents. The results showed that aromatic extracts are similar in chemical composition to fresh bitumen. The chemical nature of Triglycerides/Fatty acids and tall oils may increase the moisture sensitivity and the rate of bitumen degradation. Also, the high oxygen content in these materials reduces the long-term performance of bitumen. The FTIR spectra of aromatic extracts, paraffinic oils, and naphthenic oils are similar to those of fresh bitumen. Mohammadafzali et al. [7] found that the effect of rejuvenators on the long-term performance of bitumens depends on the type and amount of rejuvenators.

Many studies have investigated the immediate effect of recycling agents on the properties of aged bitumen. However, understanding how the restored bitumens behave and characterize them in the next period of service is quite limited. Therefore, the aim of this study was to evaluate the immediate and long-term effect of a naphthenic recycling agent in restoring the properties of aged bitumen.

2. Methodology

In this study, 60/70 penetration grade was used as the base bitumen. Aged bitumen was obtained by performing an aging simulator test (RTFO+PAV) on base bitumen in the laboratory. To restore the properties of aged bitumen, the naphthenic recycling agent has been used. To evaluate the long-term performance of the recycling agent, the restored bitumen was subjected to long-term aging using the aging simulator (RTFO + PAV) test.

In this study, the SARA fractionation test according to ASTM D4124 was used to evaluate the stability of the colloidal structure of bitumen. FTIR test was used to investigate the chemical aging of bitumen by a carbonyl (C = O) and sulfoxide (S = O) indices. To evaluate the physical properties of bitumen samples, Penetration, softening point, and RV tests were used according to ASTM D5, ASTM D36, and ASTM D4402 standards, respectively. MSCR test according to AASHTO TP70 was performed to evaluate the high-temperature performance of bitumen samples at 64 °C. LAS test according to AASHTO TP101 was performed to measure bitumen fatigue resistance at 20 °C.

3. Results and Discussion

According to the results of the SARA test (Figure 1), the use of the naphthenic recycling agent has reduced the CI of PB bitumen by 38%, which indicates the stabilization of the colloidal structure and the restoration of the chemical composition of aged bitumen (PB). Evaluation of the long-term performance of bitumen samples shows that restored bitumen after aging has a stable colloidal structure and has better resistance to aging than base bitumen.

According to the results of the FTIR test (Figure 2), a comparison between PB and R_N shows that the presence of the naphthenic recycling agent reduces carbonyl and sulfoxide indices and this shows the effect of this agent on the chemical structure of aging bitumen and its anti-aging properties. Also, the carbonyl index of PR_N bitumen is lower than PB, which indicates that this bitumen has less oxidation potential than base bitumen.

According to the results of physical tests, the naphthenic recycling agent restored the physical properties of the aged bitumen to the base bitumen level. Which indicates the high restoration properties of this substance.

According to the results of the MSCR test (Figures 3 and 4), adding the naphthenic recycling agent to the aged bitumen increased the J_{nr} value of R_N to level B. Therefore, it is observed that this agent results in the same rutting performance as the base bitumen. Investigation of the long-term performance of the recycling agent shows that the value of the R has increased with the aging of the restored bitumen.

According to the results of the LAS test (Figure 5), the use of the naphthenic recycling agent increases the fatigue life of aged bitumen to the base bitumen level. The results also show that the restored bitumen has better performance in the long-term than the base bitumen.

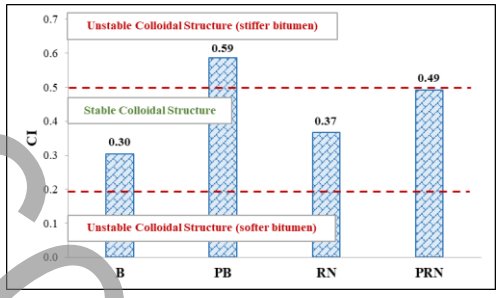

Fig. 1. Colloidal index of different bitumen samples

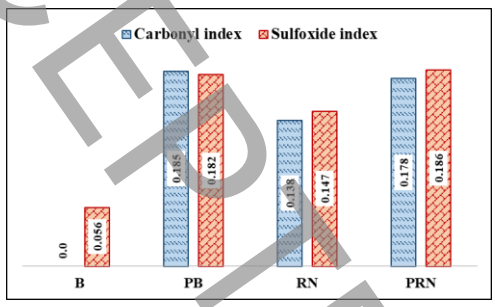

Fig. 2. Carbonyl and sulfoxide index for different types of bitumen samples

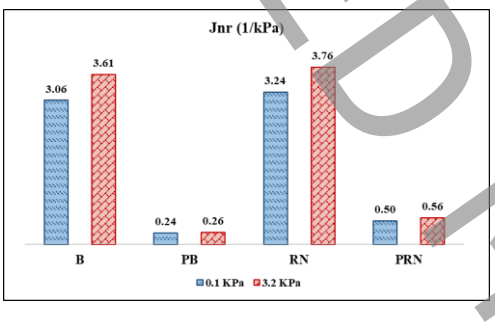

Fig. 3. Non-recoverable creep values (J_{nr})

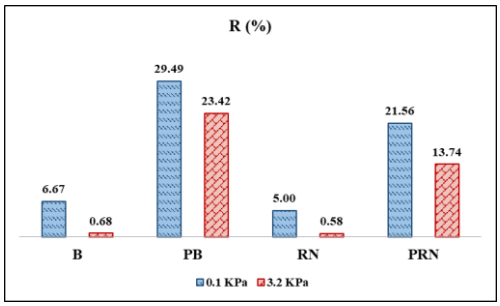

Fig. 4. Elastic recovery percentage values

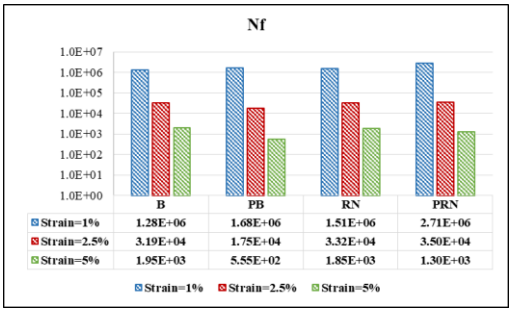

Fig. 5. Fatigue life diagram of bitumen samples at strain levels of 1, 2.5, and 5%

4. Conclusions

The most important results obtained in this study include the following:

- The naphthenic recycling agent has led to the restoration of the chemical composition of aged bitumen, which is almost similar to base bitumen. The results indicate better resistance of restored bitumen than base bitumen against aging.
- The carbonyl index of restored bitumen increased less in the long-term than the base bitumen, which indicates the lower oxidation potential of this bitumen than the base bitumen.
- The addition of naphthenic recycling agent to the aged bitumen results in the same rutting performance as the base bitumen.
- The bitumen restored by naphthenic recycling agent in the long-term had better fatigue performance than the base bitumen.

5. References

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