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INVESTIGATION OF POLIMERIC-BITUMEN BINDER SUBJECT TO CLIMATIC SERVICE CONDITIONS

SALTANAT ZH. KENBEILOVA*, ERENGAIP M. SHAIHUTDINOV[a], GALINA I. BOIKO[a], NINA P. LYUBCHENKO[b] and SERGEY A. DERGUNOV[c]

117 Kabanbay Batyr Str., Apr. 4, Almaty, KAZAKHSTAN
[a]Institute of Geology and Oil Gas, Chemical Technology, 22 Satpayev Str., Almaty, 050000, KAZAKHSTAN
[b]UNAT, 22B Satpayev Str., Almaty, 050000, KAZAKHSTAN
[c]Saint Louis University, Chemistry, 3501 Laclede Ave 125, Saint Louis, MO, 63103, UNITED STATES

ABSTRACT

Oxidized bitumen was modified with waste of carbon-chain polymer production. On Superpave specifications the physic-mechanical properties of modified bitumen were subject to investigation under the climatic conditions of the Republic of Kazakhstan. The behavior of BND60/90 bitumen and polymeric-bitumen binders has been studied at high temperatures on a dynamic shear rheometer (DSR) in the range of temperatures from +46°C to +88°C.

On a bending beam rheometer (BBR) in the range of temperatures from -24°C to -34.9°C a comparative study of low-temperature behavior of bitumen BND 60/90 and polimeric-bitumen binders BPV/OAPP-L3, BPV/OAPP-L4, GSV/OAPP -L5 after consecutive accelerated aging of samples in the vertical rotary kiln by RTFOT method and long-term aging in a pressure vessel and heat by PAV method. According the results of the Superpave specifications test samples correspond to the climatic conditions in most parts of the Republic of Kazakhstan.

Key words: Polymeric modifiers, Bitumen road viscous, Temperature constancy, Asphalt, manufacture.

INTRODUCTION

One of the most important ways to increase the operational reliability of asphalt concrete pavement is to improve the quality of bitumen by improving their production processes and technical requirements applicable to the raw materials, and modify the

*Author for correspondence; E-mail: sal-japaspai@mail.ru, amtek@bk.ru, sdrgunov@slu.edu; Ph.: 87019511251, 8(727)2925787, 9014386719

bitumen with polymeric additives. Polymeric modifiers can significantly improve the adhesion, durability, and stability properties of bitumen, add flexibility to polymeric-bitumen composition, lower the brittleness temperature, increase heat resistance, and expand the temperature range of road surface performance[1]. Adding the modifier helps to change the structure of the oil bitumen, also it is noted that the modifier molecules should be able to interact with components of the bitumen: asphaltene, resins and oils[2].

One of the ways to reduce operating costs is to use man-made materials as polymer modifiers-waste of plastic processing. The level of application of polymer waste is low, despite the potential usefulness of most of them for re-processing into valuable chemical products and collect types of raw materials.

One of these modifiers is atactic polypropylene (APP) a by-product of the isotactic polypropylene production.

A number of papers indicate a high workability of APP in the preparation of asphalt mixtures[1-4]. In addition, atactic polypropylene easily lends itself to chemical and radiation-chemical modification, which allows obtaining a new chemical product with the required set of physical and chemical properties.

Technology of thermal oxidation, radiation graft polymerization have a practical value for the modification of APP to control the hydrophobic-hydrophilic balance and surface-active properties of the polyolefin through the introduction into a macromolecule of the polar functional groups of different chemical nature (hydroxyl, carboxyl, carbonyl, ether). Given the economic and environmental factors, functionalized (modified) APP certainly is of great interest for modification of oxidized bitumen[4].

The aim of this work is to study the compliance of the polymeric-bitumen binder properties with operating conditions in different temperature range by Superpave method.

EXPERIMENTAL

This paper states the results of investigation on the physical and operational properties of oxidized bitumen BND60/90 produced by Pavlodar Oil Chemistry Refinery (POCR), of modified low-oxidized atactic polypropylene OAAP-N produced by “Ataktika”, Tomsk (Russia).

Low-oxidized APP (OAPP-L) is multifunctional modifier with a unique structure and a set of operational properties, which are formed by thermo-oxidative breakdown of APP at 180°C, the oxidizing period, makes up 2 hours:

- Contains olefin double bonds, polar hydroxyl and carbonyl groups in the macromolecule;
- Displays a high reactivity toward the poly associated bitumen components (carbines carbides, graphite structure).

To assess the effect of OAPP-L on the properties of bitumen a binder samples containing additives in the amount of 3%, 4%, 5% by weight of the bitumen are prepared.

The procedure for preparing polymeric-bitumen binder (PBB)[3]: The 1-Liter reactor furnished with a stirrer, an electric heater and temperature controller were charged with 485 g (97 wt. %) of bitumen of BND 60/90 grade, the reactor was heated up to 150 -160°C and kept at that temperature until completely melted. When constant stirring, 15 К (3 wt. %) low-oxidized APP is added.

Physical and mechanical properties of PBB were determined using a standard method for ST RK 1025-2004 "Bitumen and bitumen binders. Polymeric-bitumen binders for road construction. Specifications" as defined in the standard test methods[5].

Studies of the thermal stability of bitumen, modified OAPP-L were held in the testing laboratory of JSC "Kazakh Road Research Institute" (KazDRRI), Almaty according to the Superpave specifications[6], using modern techniques and equipment to enable similar test conditions to actual application conditions of PBB.

RESULTS AND DISCUSSION

Behavior of bitumen BND60/90 and PBB at high temperatures has been studied in a dynamic shear rheometer (DSR) in accordance with AASHTO T 315-08 [7] in their initial state and condition aged in a vertical kiln (RTFOT) per standard ASTM D 2872-08 [8]. The tests were conducted at temperatures ranging from + 46°C to +88°C. This temperature range was proved possible coating temperature in the regions with the traffic conditions[9]. Under the results of tests there were built a temperature dependence of complex shear modulus G* (kPa), the phase angle δ (deg) and the ratio G*/sin (δ) of bitumen BND 60/90 and PBB. As an example, Figs. 1-3 show above dependences for all the samples tested after aging in RTFOT. Also the temperature dependence of the complex shear modulus of bitumen BND 60/90 and PBB is nonlinear. Moreover, the degree of non-linearity increases as the temperature decreases. Above 80°C all tested bitumen have the same complex shear modulus less than 1 kPa and with temperature decrease the difference in the G* values of bitumen BND60/90 and PBB increases and at 46°C it reaches 27-36 kPa.

The phase angle of the bitumen BND60/90 and PBB also varies non-linearly based on temperature, increasing with temperature rise. A temperature dependence of the resistance of bitumen BND60/90 and PBB to rutting G*/sin (δ) for all tested samples is similar to the temperature dependence of their complex shear modulus G*.

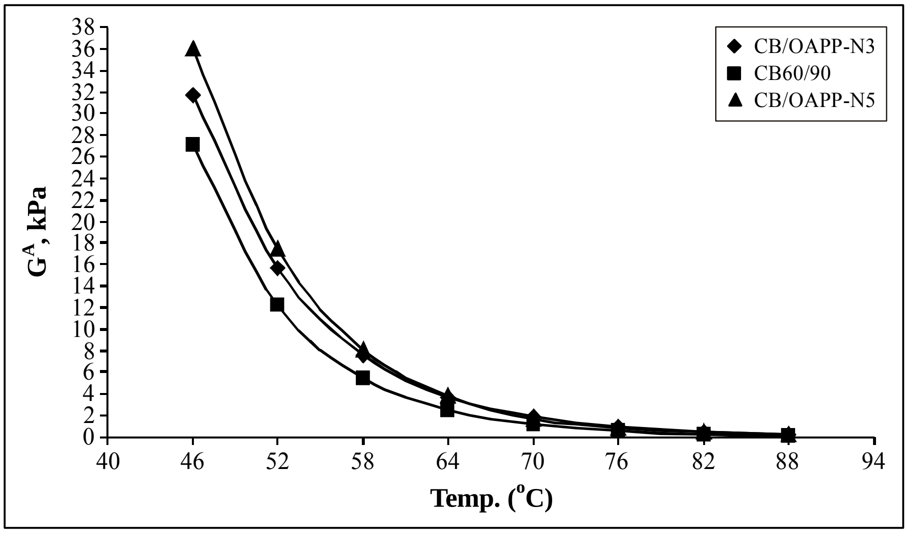

Fig. 1: The temperature dependence of the complex shear modulus of bitumen after aging (RTFOT)

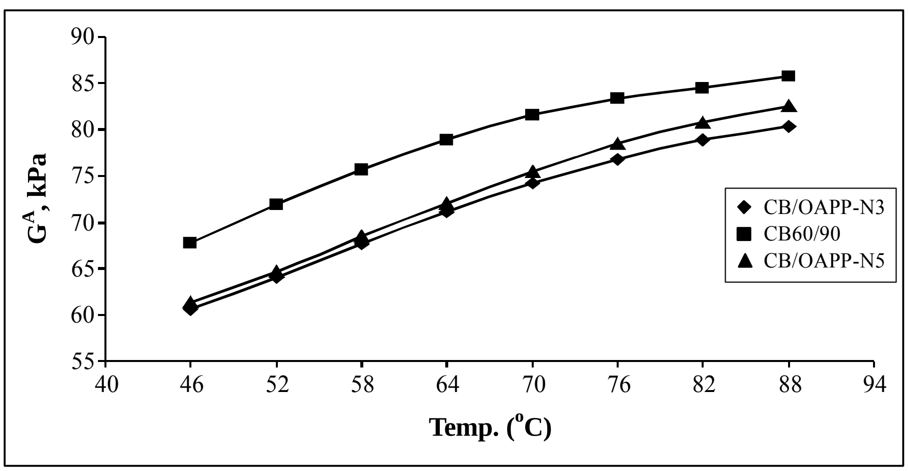

Fig. 2: The temperature dependence of the phase angle of bitumen after aging (RTFOT)

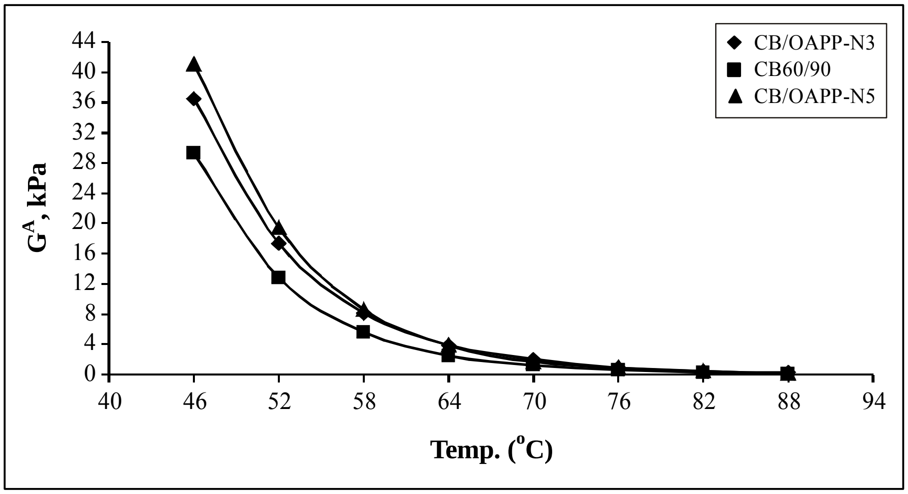

Fig. 3: The temperature dependence of the stability of the asphalt rutting after aging (RTFOT)

Superpave technical standards[6] from the condition to prevent rutting on roads require that at maximum design temperature a minimum allowable ratio G*/sin (δ) for bitumen in the original state is at least 1.0 kPa, and after aging in RTFOT – at least 2.2 kPa. For the territory of Kazakhstan per a map elaborated by "KazDRRI"[9] of zoning on operational temperatures of asphalt surfaces (Fig. 4).

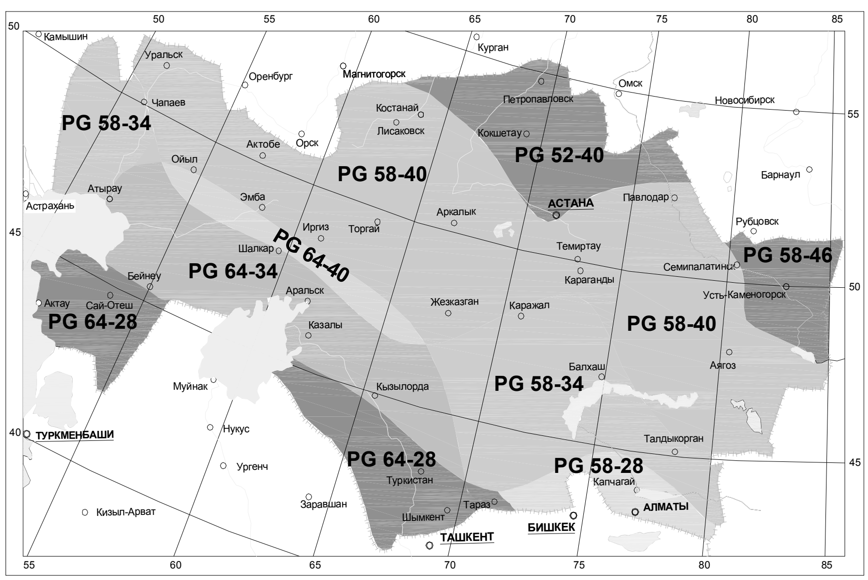

Fig. 4: Zoning of Kazakhstan on operational temperatures of asphalt pavement

The estimated maximum temperature have been set equal to + 52, + 58, + 64°C. Analysis of test results of samples on DSR subject to Superpave requirements and prospective traffic and its composition on the roads of the Republic showed that PBB of grade PBB/OAPP-L3, PBB/OAPP-L5 meet the requirements of high stability at temperatures of +52°C and below, and BND 60/90 bitumen at temperatures of + 46°C and below. Investigation of the stability of PBB grade PBB/OAPP-L3, PBB/OAPP-L4, PBB/OAPP-L5 to low-temperature cracking was carried out on a bending beam rheometer (BBR method) of Applied Test Systems (U.S.), in a range of temperature variations from -24°C to -34.9°C, which meet the design temperature of -34 to -44.9°C per the standard ASTM D 6648-08[10].

Binder samples aged under RTFOT method were subjected to lasting impact of high pressure (2.1 MPa) and temperature 100°C by PAV method[11] for 20 hours on the equipment manufactured by Prentex Alloy Fabricators, Inc, USA. PAV method simulates the effect of long-term climatic aging of a binder in service of covering for 10.5 years of service.

Samples prepared to test on BBR being result of the impact of all three stages of their life: at baseline, after mixing, and construction (RTFOT), and after aging in the manufacturing and operation process (PAV), were used for the production of bitumen cross members and testing at low temperatures.

Figs. 5-6 show the curves of displacement changes and stiffness in time for the sample of initial bitumen and bitumen binders after consecutive aging by methods RTFOT and PAV. It is seen that yield for all PBB samples and of the initial bitumen BND 60/90 with the increase of time and temperature of the load increases and the stiffness S (t) reduces.

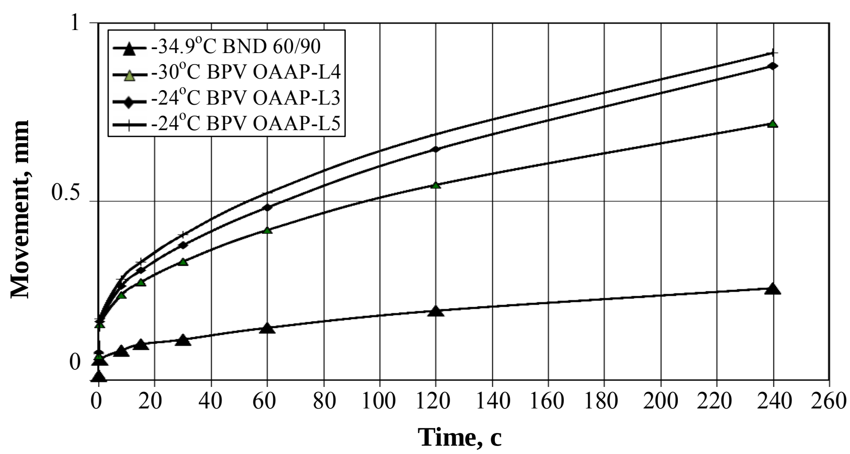

Fig. 5: Change of time travel to the bitumen and polymeric-bitumen binders after aging in RTFOT + PAV

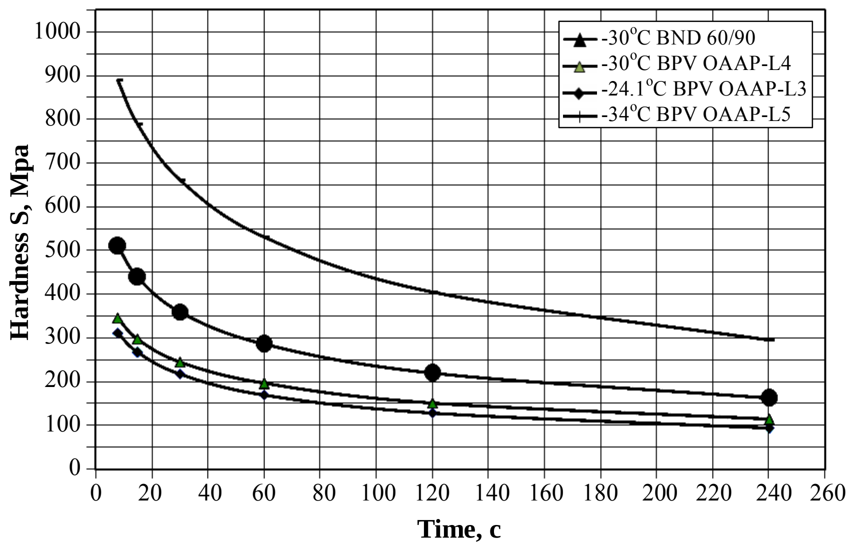

Fig. 6: Change in hardness with time for bitumen and polymeric-bitumen binders after aging in RTFOT + PAV

Study of the dependence of the stress relaxation rate (m index) in time for bitumen BND 60/90 and PBB brand PBB/OAPP-L5 at temperature range -24 to -34.9°C showed that with increasing time stress relaxation rate m (t) increases (Fig. 7). By the ability to relax (damping) the emerging stresses and to prevent residual strains appearance, the modified bitumen samples slightly differ from the original bitumen, m-value is over 0.300, which meets the technical Superpave requirements.

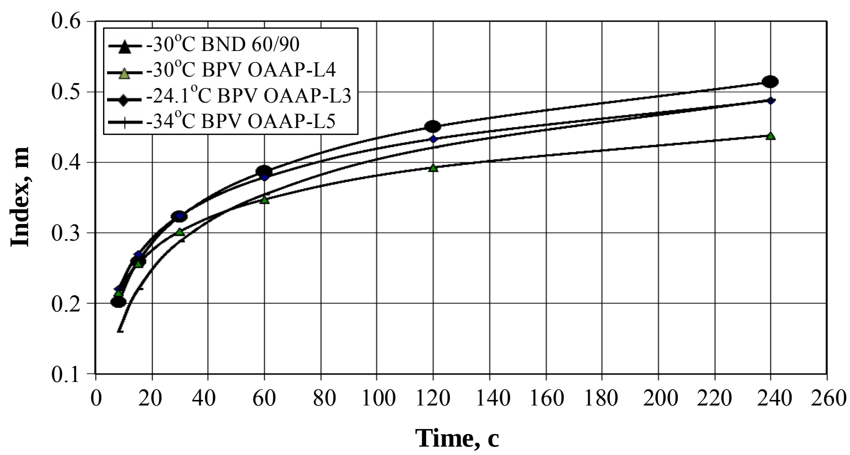

Fig. 7: Dependence of the rate of stress relaxation (index m) in time for the bitumen and polymeric-bitumen binders after aging in RTFOT + PAV

Figure 4 shows the temperature dependence of stiffness modulus at loading time 60 s and a maximum limit of stiffness modulus of 300 MPa for bitumen BND 60/90 and PBB of various grades after aging in RTFOT and PAV. According to Figure 8 modified samples at low temperatures (-24.2°C to -31.8°C) are more elastic than the original oxidized bitumen. Low-temperature cracking for 60s at 300 MPa hardness relates to the original bitumen at temperature -30.5°C, while for the PBB at a temperature of -31, 5 to -31.8°C. Among the grades studied, the best is BPV/OAPP-N4. With further decreasing temperature, low temperature cracking increases. The results of tests by BBR method showed that the polymeric-bitumen binder samples meet the requirements for low temperature stability at design temperatures: -28, -34, -40°C. In line with the Kazakhstan zoning map developed by JSC "KazDRRI" per operational temperatures[9], asphalt coatings can be used in all regions of Kazakhstan, except for the East part (-46°C).

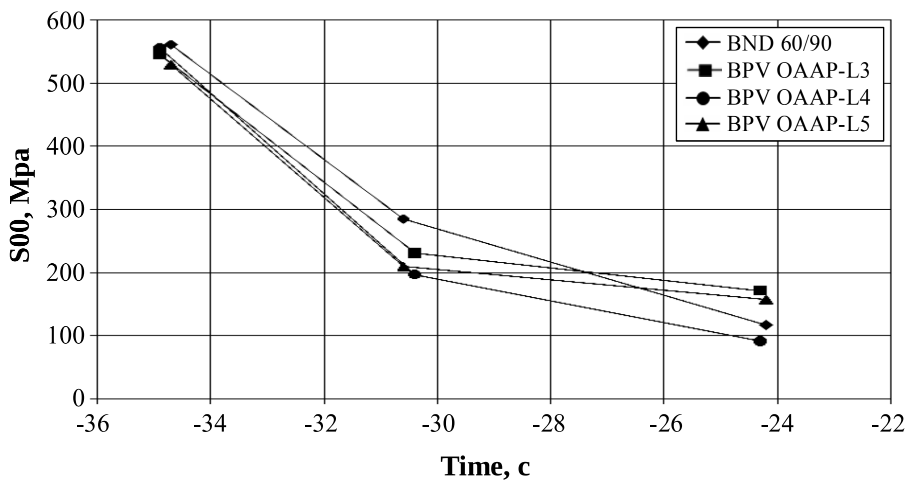

Fig. 8: The temperature dependence of rigidity modulus for bitumen BND 60/90 and polymeric-bitumen binder of various grades after aging in RTFOT + PAV (loading time 60 s, the maximum limit of the rigidity modulus of 300 MPa)

CONCLUSION

(i) The performance of oxidized bitumen BND60/90 and PBB was studied, simulated in three stages of their life: in the initial state and after aging in a vertical rotary kiln (RTFOT); pressure aging vessel at high temperature (PAV).

(ii) Analysis of PBB test results compared to the BND60/90 on DSR show strength at high temperatures, i.e. more heat resistant.

(iii) Analysis of PBB test results compared to the BND60/90 on BBR demonstrate flexibility at low temperatures, i.e., more freeze-resisting.

(iv) According to Superpave specifications test samples correspond to the climatic conditions in most parts of the Republic of Kazakhstan.

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