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Effect of Modifiers of Different Classes on Bitumen Aging Processes

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Abstract: *Some modifiers, such as heavy pyrolysis resin, petroleum resins with functional groups (carboxyl and hydroxyl), sulfur, rubber crumb and complex modifier are capable to slow down the aging process in petroleum bitumen during pavement operation. In this work such abilities were compared. The objects of the study are BND 60/90 oxidized paving bitumen produced by PJSC "Ukrtatnafta" (Kremenchuk, Ukraine) and BD 130/200 residual bitumen obtained as a result of Orkhov oil refining at JSC "Ukrgazvydobuvannya" (Lviv, Ukraine), an entity of Naftogaz group. After heating the modified BND 60/90 bitumen by RTFOT method, the best results were observed for the samples modified with petroleum resins with hydroxyl groups, complex modifier and heavy pyrolysis resin. For BD 130/200 the best results were found for the samples with heavy pyrolysis resin and sulfur.*

Key Words*: Bitumen, Bitumen Aging, Oxidized Bitumen, Residual Bitumen, Pavement.*

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I. Introduction

The quality of asphalt concrete is largely determined by the properties of bitumen, which serves as a binder and provides the formation of monolithic road-building material from individual mineral grains. Among all components of asphalt concrete, bitumen is the most sensitive to external factors, and therefore, its behavior has a decisive impact on the service life of the pavement. Bitumen becomes plastic at elevated temperatures resulting in occurrence of deformations in the form of tracks on the pavement surface. At low temperatures, bitumen becomes brittle and cracks are formed on the road pavement. Moreover, due to poor adhesion of bitumen to the surface of most mineral materials a lot of pitting, shallow holes and potholes are formed under the destructive action of water.

When using bitumen as a component of the pavement, the loss of its binding properties is inevitable. The process that takes place in such a case is called bitumen aging. Despite the fact that a significant deterioration of the binder properties is observed still at the technological stage due to various technological operations, as well as during binder preparation and storage in tanks, a significant percentage of properties are lost during operation. The main factors which negatively affect the thin bituminous film and cause the destruction of the pavement surface are atmospheric oxygen, water, solar radiation, high ambient temperatures and the action of mechanical loads from car wheels.

Therefore, the use of different additives is a prerequisite for the creation of high-quality binders and the investigation of their effectiveness will allow to choose the best additives and conditions for their use in the design of roads.

II. Materials and Methods

Conditions for bitumen modification were selected for each class of additives, taking into account their characteristics and optimal mode of operation. The broad-spectrum complex modifier (CM) consists of 5 wt.% of phenol-cresol-formaldehyde resin (Fix-F), 1.5 wt.% of Calprene 501M thermoelastoplast (a linear block-copolymer of styrene and butadiene) and 4.0 wt.% of tar, which is used as a plasticizer. The parameters of bitumen modification using CM were as follows: modification temperature is 190ºC and modification time is 60 min [1-4].

The next class of modifiers includes products of hydrocarbon pyrolysis. In order to rationally use pyrolysis liquid products, petroleum resins with carboxyl and hydroxyl functional groups (PR (C) and PR (H), respectively) were obtained [5]. Pyrolysis heavy resin (HRP), the main components of which are bicyclic, tricyclic and polycyclic aromatic hydrocarbons (51-67 wt. %), as well as resins and asphaltenes (24-39 wt.%), was used in its pure form [6]. Modification using HRP was performed at a temperature of 190 °C and time of 2 hours; the optimal amount of this additive (5 wt.%) was determined experimentally. Modification using petroleum resins with functional groups was performed under the same conditions.

The introduction of rubber crumb (RC) to the binder (RC diameter is 0-1 mm, amount is 5 wt.%) took place at a temperature of 170 ºC, under stirring for 3 hours. Similar modification conditions were for sulfur (S).

The following quality indicators were determined according to the standard methods: softening point [7], penetration at 25 °C [8] and elongation (ductility) at 25 °C [9].

Resistance to hardening under influence of heat and temperature was determined according to RTFOT method [10-12].

The characteristics of bitumen with different classes of modifying additives were evaluated according to the standard indicators for every class [13-15].

III. Results

The main indicators of the obtained modified bitumen are given in the diagrams (Fig. 1-7).

Penetration at 25 °C before and after heating for seven samples of BND 60/90 bitumen is given in Fig. 1, for six samples of BD130/200 – in Fig. 2.

Figure 1 shows that all samples of BND 60/90 modified bitumen, except for CM-modified bitumen, do not meet the standard requirements. The lowest value of penetration at 25 °C (28 0.1 mm) was found for bitumen with sulfur as a modifier.

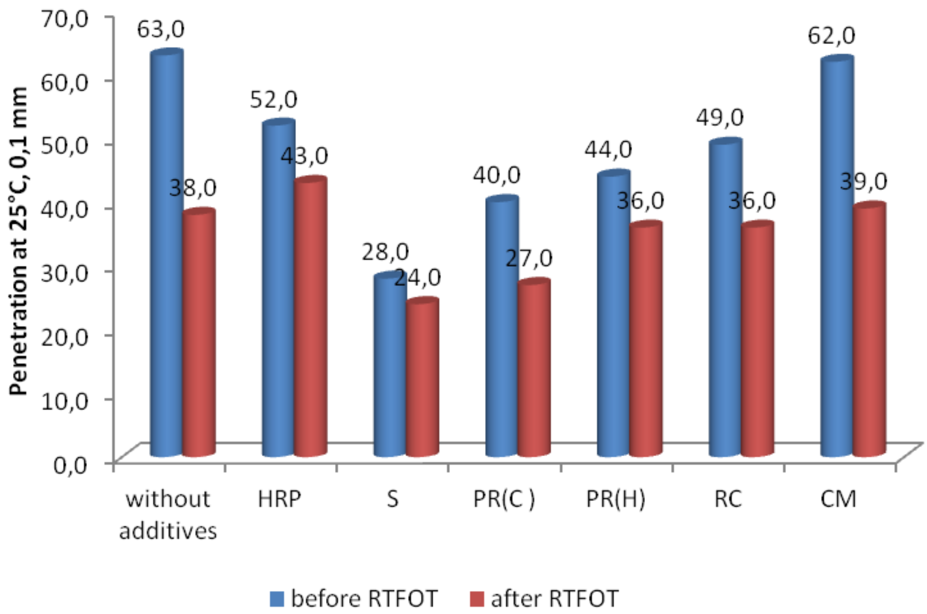

Figure 1 – Penetration at 25°C for the samples of BND 60/90 modified bitumen

For residual bitumen (Fig. 2) the best penetration results are observed for the samples modified with sulfur and HRP (143 and 148 0.1 mm, respectively). The worst results are observed when petroleum resins as the modifiers were used (for PR (H) penetration is 92 0.1 mm). This modified bitumen does not meet the requirements.

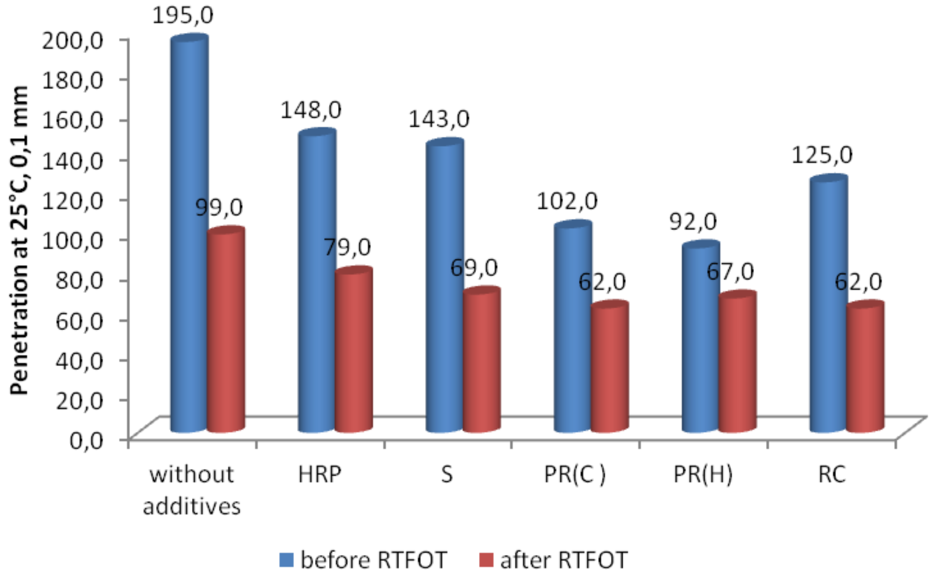

Figure 2 – Penetration at 25°C for the samples of BD 130/200 modified bitumen

The softening point before and after heating by the RTFOT method for seven samples of BND 60/90 modified bitumen are shown in Fig. 3, for six samples of BD 130/200 – in Fig. 4.

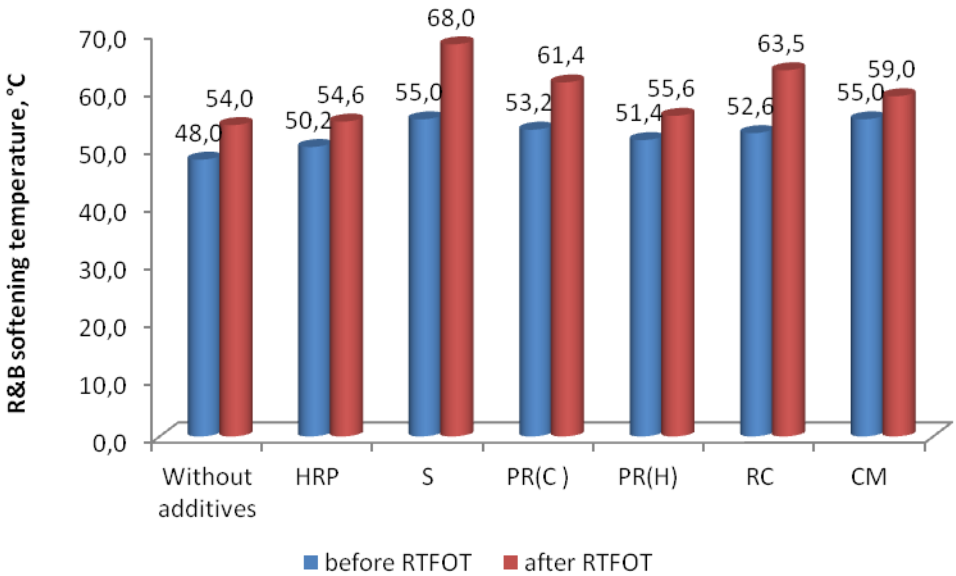

Figure 3 – Softening point for the samples of BND 60/90 modified bitumen

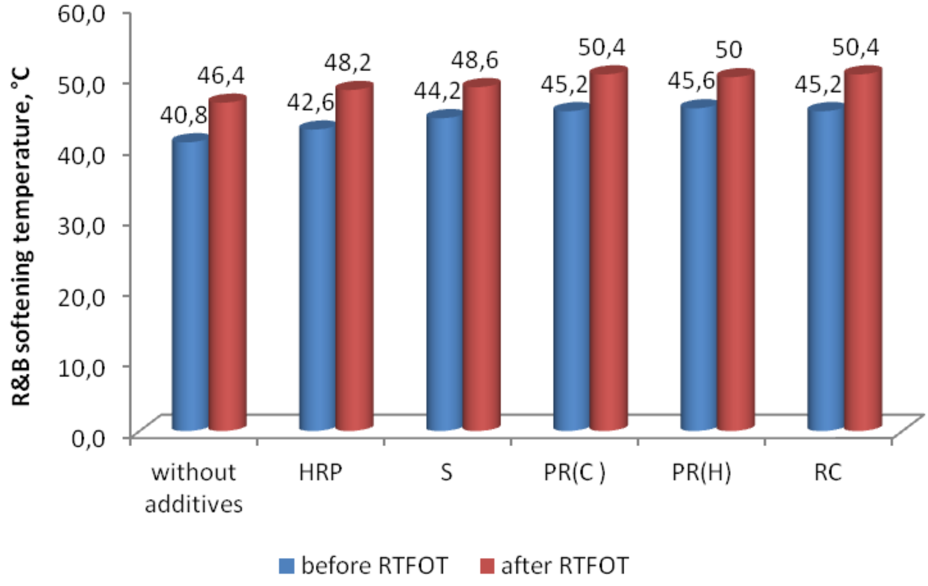

Figure 4 – Softening point for the samples of BD 130/200 modified bitumen

It is obvious from Figure 3 that the softening point of BND 60/90 bitumen modified with sulfur, rubber crumb and complex modifier meets the requirements of the standard does not meet the standard for the samples modified with petroleum resins and heavy pyrolysis resin. According to Fig. 4, only one sample meets the requirements; it is RC-modified bitumen.

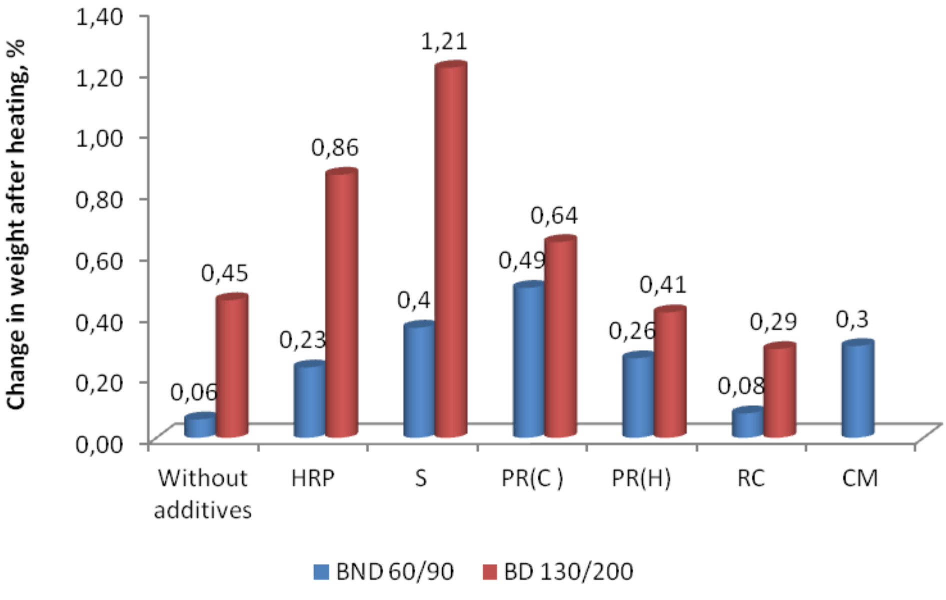

Figure 5 – Change in weight after heating by RTFOT method for BND 60/90 and BD 130/200 modified bitumen

In terms of change in weight after heating by RTFOT, all samples showed very good results and are within standard limits.

Ductility at 25 °C before and after heating for seven samples of BND 60/90 bitumen is given in Fig. 6, for six samples of BD 130/200 – in Fig. 7.

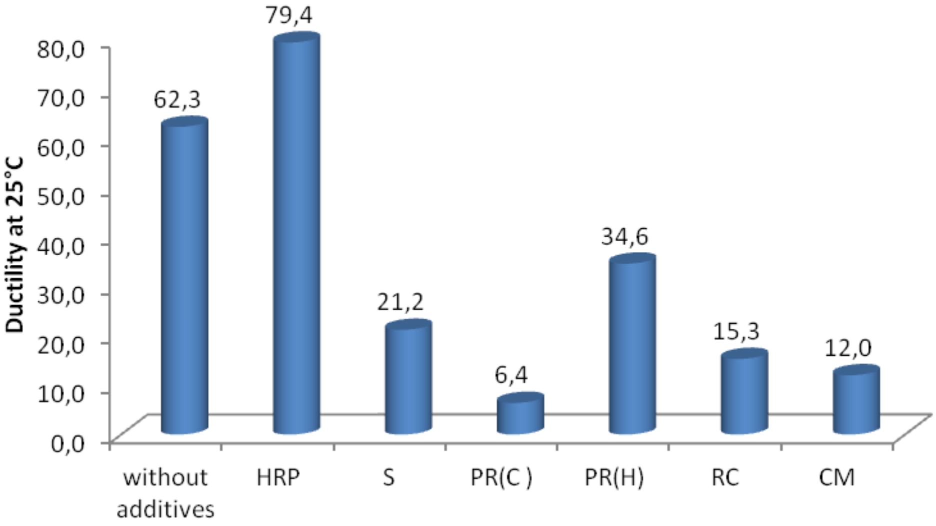

Figure 6 – Ductility at 25 °C for the samples of BND 60/90 modified bitumen

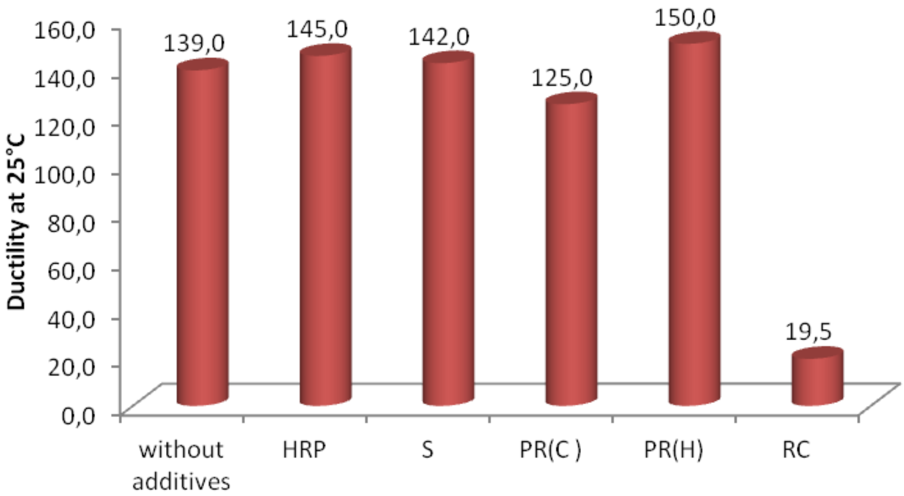

Figure 7 – Ductility at 25 °C for the samples of BD 130/200 modified bitumen

All samples meet the standard requirements (Fig. 6 and 7) Moreover, almost all samples of BD 130/200 are at a very high level, which is explained by the use of highly resinous oil used for the production of this binder [16].

IV. Discussion

When comparing the obtained results, the following regularities can be seen: during the heating process the required resistance to hardening is demonstrated by BND 60/90 bitumen modified with HRP, S and PR (H). The results obtained for other samples are unsatisfactory.

As for DB 130/200 samples, the satisfactory results in regard with penetration were obtained for PR (C) and PR (H) modified bitumen. However, due to the low values of resistance to aging, further application of mentioned modifiers needs improvements.

During the heating process of BND 60/90 bitumen, the change in softening point is within the normal range for the samples with CM, PR (H) and HRP modifiers, for other samples the change is too large. With regard to BD 130/200 bitumen, it should be noted that all modified samples meet the necessary requirements.

The change in weight after heating for all samples is also within the required requirements.

Thus, it can be argued that heavy pyrolysis resin as a modifier provides the best aging resistance for BND 60/90 bitumen; the modifiers PR (H) and CM show good results. However, their use requires some improvement in the initial composition of bitumen, which would allow to obtain binders that meet absolutely all requirements.

For BD 130/200 bitumen the best results were observed with HRP and sulfur as the modifiers, although their further use also requires some changes in the modifier composition.

V. Conclusion

The use of bitumen as a binder for road pavement inevitably generates various types of chemical and structural changes in asphalt concrete. After several changes of seasons this fact results in the destruction of the road surface due to the combined action of natural and mechanical factors. The appearance of cracks, potholes and pits, as well as the formation of tracks are observed. Therefore, to ensure the good properties of the binder, it is necessary to use modifying additives of different classes.

Every year various modifying additives appear on the Ukrainian market, which requires a comprehensive study of bitumen and asphalt concrete modified by these additives, in order to determine the effectiveness and nature of their action, as well as the most efficient technologies for their use.

It was found that heavy pyrolysis resin, sulfur, complex modifier and petroleum resins with hydroxyl groups as bitumen modifiers showed the best results among investigated modifiers regarding the bitumen resistance to hardening under the influence of heat and air. At the same time, all modifiers provide high results in improving the binder quality, which in turn will increase the service life of pavements.

Taking into account these and other results, we can guarantee that the use of quality bitumen and their modification with effective additives will significantly improve the properties of asphalt concrete and increase the service life of the road surface. High qualitative characteristics of bitumen will allow to extend the service life of the pavement and to save energy, material, human and financial resources.

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