The effect comparative evaluation of energy-saving additives on the bitumen properties

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Abstract. Energy-saving additives used in the Uzbekistan road construction practice are considered. Based on experimental data, the influence of the considered energy-saving additives on the standard, adhesive and rheological properties of petroleum road viscous bitumen has been established.

1 Introduction

The preparation of asphalt concrete mixtures and the construction of road surfaces from them are material- and energy-consuming processes. According to A.V. Rudensky [1], from 40% to 50% of the total energy consumption for the installation of asphalt concrete coatings is spent on the preparation of asphalt concrete mixtures. At the same time, the predominant amount of energy resources is spent on heating stone materials and bitumen binders to process temperatures. In turn, high technological heating temperatures of the components of asphalt concrete mixtures lead to intensive release of harmful substances into the atmosphere (nitrogen oxides, CO, CO_2, etc.) In this regard, issues related to resource conservation and energy conservation in the production of asphalt concrete mixtures are relevant.

The first coatings made of "warm" asphalt concrete mixtures in Europe were developed in 1996. In 1999 In Norway, formulations have been developed using two-stage WAM-Foat technology based on the pretreatment of stone materials with less viscous bitumen and subsequent combination with foamed viscous bitumen. In Hamburg using the additive Aspha-min [4]. Since 2004 The use of "warm" asphalt concrete mixtures was started in the USA. In Uzbekistan, researches of energy-saving additives have been conducted since 2009, and asphalt concrete based on them throughout 2010-2011.

Energy-saving additives used in the preparation of "warm" asphalt concrete mixtures have a wide, constantly replenished nomenclature and are divided into two types: organic and chemical [7, 8]. Organic additives include waxes (Fischer-Tropsch and Montana's) and fatty acid amides (Asphaltan, Sasobit, Licomint). According to the developers, the principle of their operation is based on a sharp decrease in the viscosity of bitumen binders at process temperatures exceeding the melting point of the additive. In the field of operating temperatures, organic energy-saving additives, as a rule, contribute to the hardening of the binder (a decrease in penetration at 25 ° C and an increase in viscosity) and an expansion of the plasticity interval due to a significant increase in the softening temperature.

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Sasobit is one of the first energy-saving additives that were used to prepare "warm" asphalt concrete mixes [2, 4]. The additive is a fine-grained crystalline substance, artificial high molecular weight paraffin wax (aliphatic hydrocarbon with a hydrocarbon chain length - C40 ... C 115), obtained by Fischer-Tropsch synthesis. According to the manufacturer, Sasol Wax, the melting point of the additive is in the range from 85°C to 115°C. At temperatures above 120°C, Sasobit completely dissolves in bitumen, forming a spatial crystal structure during cooling [9]. In European countries, the dosage in bitumen is 2.5% of the binder weight, in the USA – 1.0... 1.5% [7].

The use of Sasobit allows to reduce the temperature of preparation and compaction of asphalt concrete mixtures by 10 - 30°C [2, 7, 10]. At the same time, the introduction of the Sasobit additive in an amount of 3% into oxidized bitumen of different brands allows to reduce the technological temperatures of preparation of asphalt concrete mixtures, established by temperature - viscosity dependencies, by only 5 - 8°C.

It is generally accepted to introduce Licomont BS 100 into bitumen in an amount of 3%. Local and foreign researchers have noted that the modification of bitumen with Licomont BS 100 additive is accompanied by an increase in the softening temperature to a greater extent than with the introduction of equal concentrations of Sasobit.

The Licomont BS 100 additive inclusion leads to a greater decrease in the viscosity of the binder at process temperatures than the Sasobit additive [14-15]. According to [12] Licomont BS increases the adhesion of bitumen-mineral mixtures determined by the "rotating bottle" method. Asphalt concretes based on bitumen modified by Licomont BS 100 are characterized by higher strength properties and increased track resistance, due to which they are recommended to be laid in places with increased load [7]. The constant expansion of the range of energy-saving additives requires regular research aimed at establishing their effect on the bitumen properties and asphalt concrete.

The aim of this work is a comparative assessment of the impact on the petroleum road bitumen properties of energy-saving additives used in the road constrution in Uzbekistan - Sasobit and Licomont BS 100, as well as the new Selena SX105 additive. To achieve this aim, the influence of energy-saving additives adopted in the work on the road bitumen properties has been established, according to the O'z DSt 3074:2016 requirements [18].

2 Methods

BND 90/130 bitumen of local production was adopted as the initial bitumen for the preparation of bitumen binder. Sasobit, Licomont BS 100 and Selena SX105 were used as energy-saving additives, the appearance of which is shown in Fig. 1.

Bitumen modification with energy-saving additives in the amount of 5 and 6% was carried out in a laboratory stirrer, providing a mixing speed of about 1000 rpm, at a temperature of 180°C for 60 minutes.

For bitumens modified with energy-saving additives adopted in the work, standard quality indicators were determined in accordance with those in force in Uzbekistan. In addition, indicators characterizing the properties of binders were determined: equipenetration temperature corresponding to the penetration of 800 × 0.1 mm (T_{800}); penetration index calculated from the temperature of T_{800} viscosity in the temperature range from 60 °C to 150 °C.; equiviscid temperatures corresponding to viscosities of 0.5 Pa × s (optimal heating temperature of binders in the preparation of asphalt concrete mixtures) and viscosity of 1.0 Pa×s (optimal temperature of the beginning of compaction of asphalt concrete mixtures) adhesion determined by the method of DSTU B.V.2.7-8 the edge angle of wetting in the temperature range from 90 °C to 150 °C.

Fig. 1. The additives appearance

Standard quality indicators of bitumen binders are presented in Table. 1. The properties of binders modified with energy-saving additives, considered in the work with certain concentrations, meet the requirements for almost all indicators (the exceptions are the adhesion values of binders on Licomont BS 100 and Sasobit before and after aging).

The introduction of energy-saving additives leads to the structuring of the initial bitumen, which is reflected in a decrease in penetration and ductility at 25 °C, an increase in the softening temperature. After modification of the original bitumen, the binder grade changes from BND 90/130 (according to DSTU 4044) to BMV 60/90 (according to the standards of the SOU 42.1-37641918-068) binders with 2% and 3% additives Licomont BS 100 and BMV 40/60 binders with 2% and 3% additives Sasobit have the greatest structuring effect on the initial bitumen provides 3% Selena additives, reducing penetration and ductility at a temperature of 25°C (Figure 2, Table 1).

Table 1. Standard quality indicators of bitumen binders

Property		Source bitumen	Bitumen modified with energy-saving additive			
			Licomont BS 100		Sasobit	
Marking of the binder		B	BL2	BL3	BS2	BS3
The content of the additive, %		0	2	3	2	3
Penetration at 25°C, 0.1 mm		98	75	65	57	48
Softening temperature (T_s), °C		46.9	61.2	83.2	62.1	74.0
Brittleness temperature °C		-16	-18.5	-16.5	-15	-15.5
Ductility at 25 °C, cm		129	55	47	61	37
Adhesion to glass at 85 °C, %		11.7	8.5	15.5	10.3	- 23.6
The penetration index calculated from the temperature T_s (IP T_s)		- 0.27	2.40	5.49	1.78	- 3.35
Plasticity interval, °C		62.9	79.7	99.7	77.1	89.5
The temperature at which the penetration is 800×0.1 mm (T_{800}), °C		-16	-18.5	-16.5	-15	-15.5
Penetration index calculated by temperature T_{800} (IP T_{800})		-1.19	-0.19	-0.32	-0.53	-0.31
Aging according to GOST 18180	Residual penetration, %	59.2	69.3	78.5	70.2	70.8
	Change of T_s, °C	1.5	-3.2	-23.2	0.5	7.0
	Brittleness temperature, °C	-16	-18	-18.5	-14	-17
	Ductility at 25 °C. cm	104	42	28	22	14
	Coupling at 85 °C, cm	7.7	7.6	8.3	6.8	- 13.4

Continuation of table № 1

Aging according to DSTU B EN 126607-1 (RTFOT)	Residual penetration, %	65.3	74.7	81.5	84.2	79.2
	Change of T_s. °C	2.3	-4.9	-22.3	1.7	0.6
	Brittleness temperature, °C	-15.5	-17	-18	-16.5	-14.5
	Ductility at 25 °C, cm	97	39	32	34	21
	Coupling at 85 °C, cm	8.6	6.3	11.6	5.1	- 15.1

Continuation of table № 1

Property		Bitumen modified with energy-saving additive Selena		Standards for SOU42.1-37641918-068	
Marking of the binder		BSr2	BSr3	BMV 40/60	BMV 60/90
The content of the additive, %		2	3	-	-
Penetration at 25°C, 0.1 mm		58	48	40...60	61 ...90
Softening temperature (T_s), °C		66.6	78.0	⩾ 62	⩾ 74
Brittleness temperature °C		-16.5	-16.5	⩽ -10	⩽ -12
Ductility at 25 °C, cm		51	36	⩽ 20	⩽ 24
Adhesion to glass at 85 °C, %		24.5	70.1	⩾ 32	⩾ 20.0
The penetration index calculated from the temperature T_s (IP T_s)		2.66	3.65	-	-
Plasticity interval, °C		83.1	94.5	-	-
The temperature at which the penetration is 800×0.1 mm (T_{800}), °C		-16.5	-165	-	-
Penetration index calculated by temperature T_{800} (IP T_{800})		-0.24	-0.26	-	-
Aging according to GOST 18180	Residual penetration, %	69.0	83.7	⩾60	⩾60
	Change of T_s, °C	2.0	6.1	⩽6.0	⩽6.0
	Brittleness temperature, °C	-16	-16	-	-
	Ductility at 25 °C. cm	27	17		
	Coupling at 85 °C, cm	46.8	60.3	⩾ 27.0	⩾ 15.0
Aging according to DSTU B EN 126607-1 (RTFOT)	Residual penetration, %	81.0	86.0	-	-
	Change of T_s. °C	0.2	0.8	-	-
	Brittleness temperature, °C	-17	-14	-	-
	Ductility at 25 °C, cm	22	21		
	Coupling at 85 °C, cm	31.9	66.6	-	-

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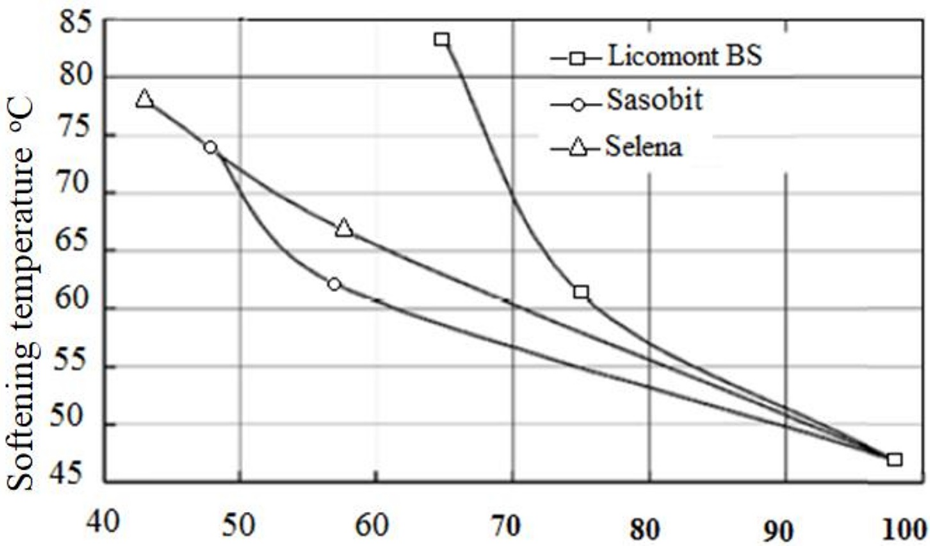

Fig. 2. Penetration at 25°C, 0.1 mm

The additives used in the work lead to a significant expansion of the plasticity interval of binders (Figure 3), which is wider the higher the concentration of additives. The increase in the plasticity interval is achieved solely by increasing the softening temperature, since the brittleness temperatures of all bitumen binders are at the level of the initial bitumen. The immutability of the brittleness temperature can certainly be attributed to the advantages of energy-saving additives, since equipenetration pure bitumen is characterized by higher values of low-temperature indicators. According to the value of the plasticity interval (94.5 °C) and temperature sensitivity (I PT_{800} = 0.26), bitumen modified with Selena SX105 additive is the most effective.

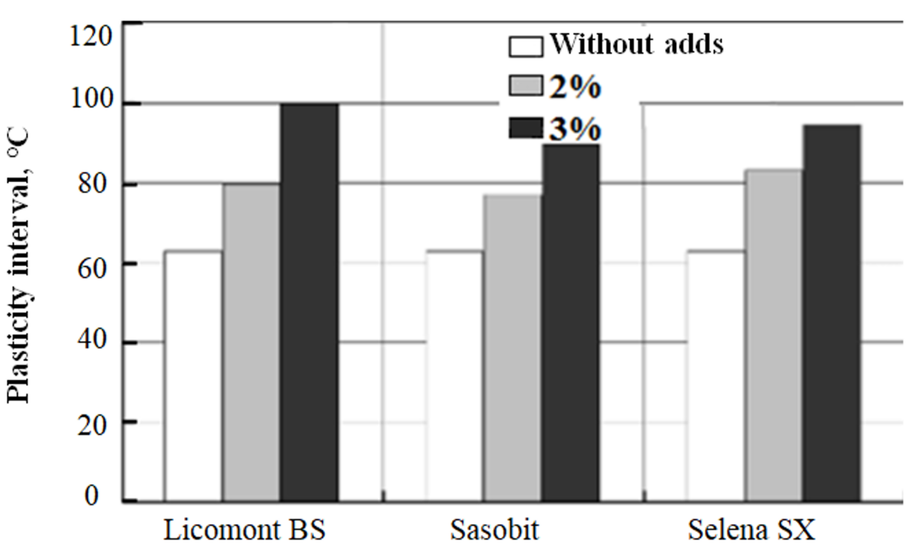

Fig. 3. Plasticity interval of binders

3 Results and discussion

Bitumen binders with the addition of Licomont BS 100 can have a plasticizing effect on asphalt concrete mixtures, which can help improve their compaction.

The advantages of binders modified with energy-saving additives include an increase in adhesive properties. When assessing the adhesion of binders to the glass surface according to the method normalized in DSTU B.V.2.7-81, with an increase in the concentration of additives, the adhesion of binders increases from 11.7% in the initial bitumen to 70.1% in the binder with 3% Selena (Figure 4).

The smallest increase in adhesion to glass is observed in binders modified with Licomont BS additive – adhesion increased to only 15.5% (with an increase in the additive content to 3%).

Based on these given data, the energy-saving effect of the use of the considered additives is also not traceable. A possible reason that the additives considered do not have a significant energy-saving effect may be the structural features of oxidized bitumen used in the road industry of Uzbekistan. Oxidized bitumen, unlike distilled bitumen used in the USA and European countries, belong to the structural type "sol-gel", similar to the type "gel", and are characterized by the presence of an internal coagulation structure of the asphaltene grid in a solution of maltenes. In this case, the plasticizing effect of the use of paraffin waxes may be significantly less than in the case of using these additives in bitumen of the structural type "sol", the properties of which are determined by the supramolecular continuous structure of resins.

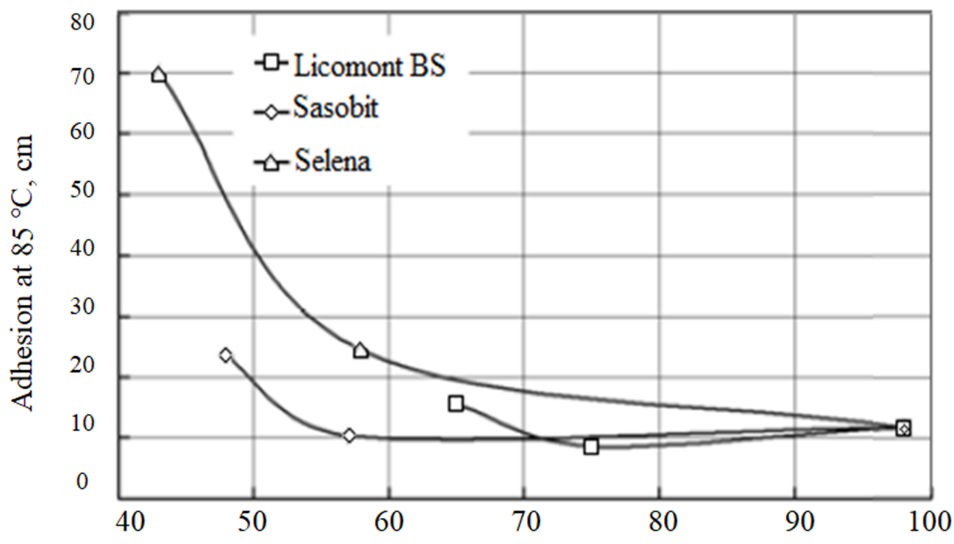

Fig. 4. Adhesion of binders to the glass surface

As a result of the conducted research, it was found that the use of Selena additive ensures the manufacturability of asphalt concrete at lower compaction temperatures, without negatively affecting the properties of bitumen and asphalt concrete based on them.

4 Conclusions

Based on the experimental obtained data, the following conclusions can be made:

1. All additives used in the study have a structuring effect on bitumen mainly, expressed in a decrease in aeration at 25°C, an increase in the softening temperature, a decrease in ductility at 25°C, a significant expansion of the plasticity interval.
2. Selena additive has the greatest structuring effect. Binders modified with Selena additive are characterized not only by a significantly increased softening temperature and a significant decrease in penetration, but also by an increase in adhesion and residual penetration, and a decrease in temperature sensitivity. This, in turn, should increase the strength of asphalt concrete prepared with modified binders.
3. For all the considered additives, no significant energy-saving effect has been established, consisting in a decrease in the technological heating temperatures of the binder during the preparation of asphalt concrete mixtures and their compaction, established by temperature-viscosity dependencies and temperature dependencies of the edge wetting angles.

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