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Modification of Physical and Mechanical Properties of Road Bitumen Polymer Wastes

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ABSTRACT: The article presents the results of studies to improve the physico-mechanical properties of oil road bitumen using polymer waste as a modifier, in particular spent polyethylene and rubber crumb. When studying the effect of the concentration and nature of the injected polymeric modifiers and plasticizers, in which M-40 fuel oil and M-12 used motor oil were used, the compositions of bitumen compositions corresponding to the BND 60/90 construction bitumen according to GOST 22245 were established-90. It is shown that the bitumen composition containing 6% polyethylene in terms of penetration at 25°C (51x0.1mm) and softening temperature (80°C) corresponds to the bitumen grade BND 60/90. Modification of oil bitumen containing 2.0-28% mass of rubber crumb secondary polyethylene showed that with the optimal concentration of M-40 fuel oil in the composition of the bitumen composition with an increase in the amount of plasticizer - secondary polyethylene from 1.4 to 4.0% (mass), the softening temperature of the final product varies from 46 to 80°C, and the tensile index from 4 to 13 cm.

KEYWORDS: modification, asphalt composition, bitumen, mineral impurities, road surface, penetration, extensibility, softening temperature

I.INTRODUCTION

Currently, bitumen compositions modified with various polymeric wastes, in particular polyisoprotein rubbers (SKI-3), divinylstyrene thermoplastic elastomer, and ethylene copolymers, are widely used to create a practical pavement propylene, waste thermoplastic polymers and production of high-density polyethylene, etc. [1-5]. The accumulated experience in the operation of pavements shows that their pre-temporary destruction is determined by the quality and complex of the physicomechanical properties of bitumen, which serves as a binder. The bonding materials used in road construction are characterized by low maintenance characteristics, which one has to carry out a major repair every 3-4 years [6]. In the current situation, in order to increase the service life of pavements, it is necessary to develop and test modified bitumen binders of improved quality capable of providing higher strength and durability of pavements by introducing either new modifiers into their composition or developing optimal conditions and modification recipes.

The purpose of this study is to replace modifiers with waste polymeric materials with high performance characteristics. In the presented work the results of studies to establish the optimal content of individual components, in particular modifying, plasticizing components in the composition of the bitumen composition on its operational properties were set out.

II.EXPERIMENTAL PART

In order to improve the quality of bitumen, we used waste products of the polymeric and tire (rubber chips) industries as a modifier. The use of rubber crumb obtained from waste as a modifier of bitumen allows to solve the environmental problem of environmental pollution by waste rubber products. Due to the organic affinity with the components of bitumen, the crumb is considered to be promising modifiers, since their incorporation into the composition of the bitumen composition ensures the adhesion of tires with a coating, reduces dust formation, helps to improve the operational properties of asphalt concrete pavements, reduces the cost of maintaining and repairing the roadway [7]. The rubber composition includes natural, isoprene, butadiene, styrene butadiene and other types of rubber, which give them valuable properties, and help to improve a number of properties of the bituminous composition. In particular, they have a lower brittleness temperature, better durability, elasticity, etc. [8].

Polymers, polymeric wastes, modified polymers or polymeric mixtures and composite materials based on them possess a complex of a number of useful physicomechanical properties: in particular, impact resistance, heat resistance,

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frost resistance, resistance to gasoline, oil, so that they can be used in heavy operating conditions. Due to these properties, they are widely used as a modifier for petroleum bitumen [4, 5, 9–13].

The determining role in the preparation of the polymer-bitumen mixture has the molecular weight of the polymer used. Due to the high chemical resistance, elasticity, mechanical strength, the use of polyolefins, in particular, polyethylene as a modifier, provides the possibility of obtaining bitumen compositions with improved performance properties [14-18]. Modification of bitumen by introducing polyethylene leads to an increase in the softening temperature and a decrease in the penetration index. The nature of the combination of bitumen with polyethylene is not fully understood. Using the low and high pressure polyethylene as a bitumen modifier, the authors found that with the introduction of 5% low pressure polyethylene and 20% high pressure polyethylene into bitumen, it is possible to produce materials characterized by equal softening temperatures and penetration [16].

In our studies, the oxidized bitumen of the BND 60/90 grade, which is characterized by a softening temperature along the "ring and ball" (RaB) -110°C (GOST 11506-73), needle penetration depth (penetration) at 25°C 16×0 , 1 mm (GOST 11501-73) and tensile properties at 25°C - 3 cm (GOST 11505-75). The modification of the specified bitumen is carried out by the introduction of recycled polyethylene (RE), as well as rubber crumb. As a plasticizer, M-40 fuel oil according to GOST 10585-99 is used, which is characterized by kinematic viscosity at 80°C - 43 mm2/s, density at 20°C - 922.1 kg / m3, pour point - minus 12°C, flash point - 184°C, ash content - 0.0228% of the mass. Mass fraction of sulfur was - 0.23%. Waste rubber products with a diameter of 0.06 mm (GOST1293), obtained by grinding waste tires in a cutting mill, were used as rubber crumb. The polyethylene modifier used is polyethylene obtained from waste from the production of window frames after single and secondary processing (PE-I), (PE-II).

Samples of bitumen compositions were prepared as follows: a mixture of bitumen and softener — fuel oil or used engine oil was heated to 60–70°C, to which, with continuous stirring, the calculated amount of modifier — rubber chips and polyethylene were added. To obtain a homogeneous mass, the temperature of the mixture, continuously mixing, was raised to 120°C, then to 160-170°C. At this temperature, bitumen liquefaction and swelling of crumb rubber are observed, to which the polymer is involved during mixing. The resulting bitumen composition was maintained for another 30-40 minutes at the specified temperature.

III.RESULTS AND THEIR DISCUSSION

In order to evaluate the modifying effect of the additives introduced into the bitumen composition, the bitumen compositions obtained by introducing only one of the specified modifying components under investigation were investigated. In the resulting modified ¬ bitumen compositions, the physico-mechanical properties were determined, which are presented in Table No. 1. From the obtained results, it can be seen that the softening rate for the RaB bitumen composition modified with the introduction of 1.4 and 4.1% of the mass of PE (II) in composition, respectively, increases from 110°C (experiment 3) to 125°C (experiment 4). At the same time, the penetration rate at 25°C practically does not change and amounts to 16×0.1 mm and 14×0.1 mm with the introduction of the modifier in the amount of 1.4%, respectively, and 4.0%.

When reducing the concentration of PE-II to 6% in the calculation of the bitumen and dissolved in a relatively smaller amount of fuel oil ~ 16% in the composition of the temperature softening at RaB to 80°C, the depth of needle penetration increases from 16x0.1mm to 51×0.1mm, and stretching at 25°C increases from 3 to 4 cm. The resulting sample, modified by PE (II), by softening temperature and in terms of stretch ability at 25°C, excluding penetration, corresponds to BND 70/30 building bitumen according to TS AZ 353 66 01 242-2015. Reducing the concentration of polyethylene to 4% by weight and the concentration of fuel oil M-40 to 13.33% by weight the softening temperature of the resulting bitumen composition decreases to 63°C, the penetration index at 25°C is 8 0×0,1mm, stretching at 25°C increases to 6 cm and the resulting composition according to the temperature of softness and penetration, with the exception of tensile properties at 25°C, corresponds to the construction bitumen grade BND 60/90 according to GOST 22245-90 .

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Table 1. Indicators modified bitumen composition

№ ofexperience	Naming	Softening temperature by RaB, °C GOST 11506-73	Depth of penetration of the needle, at 25 ° C×0.1 mm GOST 11501-73	Extensibility at 25°C, cm, GOST 11505-75
1	Bitumen oil road brands BND 60/90, GOST 22245-90	n.n. 47	61-90	n.n. 47
2	Bitumen (raw materials)	110	16	3
3	Bituminous composition,% by weight: Bitumen - 70.4 PE (II) - 1,4 FuelOil - 28.2	125	16	0,5
4	Bituminous composition,% by weight: Bitumen - 68.6 PE (II) - 4.0 Fuel Oil - 27.4	125	14	0,5
5	Bituminous composition,% by weight: Bitumen - 79.37 PE (II) - 4.76 FuelOil - 15.87	80	51	4

Similar results were achieved using as a modifying component of rubber crumb in the amount of 2.5% of the mass. At the same time, the obtained bitumen composition according to the melting point and penetration index (84×0.1 and at 25^0C), with the exception of the tensile index, corresponds to the road bitumen grade BND 60/90. The technical characteristics of the obtained bitumen compositions are given in Table 2.

A series of studies on the modification of binder bitumen for road cover was carried out using recycled polyethylene as a softener. The compositional composition with the involvement of secondary polyethylene in the bitumen composition was also carried out in the experimental part by the above method.

Table 2.Physico-mechanical properties of bitumen compositions

Naming	The softening temperature in RaB, ° C GOST 11506-73	Depths of prokaniy-kaniya needles, at 25 ° Sh0,1mm,GOST 11501-73	Extensibility, cm, at 25 ° C, n. GOST 11505-75
GOST 22245-90 for road bitumen of BND 60/90 brand	n.n. 47	61-90	55
Bitumen (raw materials)	110	16	3
Bituminous composition: Bitumen - 72.0 mass% Rubber crumb - 2.0 wt% Fuel oil - 26.0 mass%	51	95	4
Bituminous composition: Bitumen - 70.1 mass% Rubber crumb - 2.5 wt% Fuel oil - 27.4 mass%	62	84	5
Bituminous composition: Bitumen - 69.2 mass% Rubber crumb - 2.8 wt% Fuel oil - 28.0 mass%	54	90	7

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Table 3. Physical and mechanical properties of the obtained bitumen compositions

№	Naming	Softening temperature RaB, ° C, GOST 11506-73	The depth of penetration of the needle, at 25 ° Sh0,1mm, GOST 11501-73	Extensibility, cm, at 25 ° C, n. GOST 11505-75
	Bitumen (raw materials)	110	16	3
I	Experience 1. Bituminous composition: Bitumen - 70.6 mass% Polyethylene (II) - 1.4 wt% Fuel oil - 28.0 mass%	46	71	13
II	Experience 2. Bituminous composition: Bitumen - 69.4 wt% Polyethylene (II) - 2.8 wt% Fuel oil - 27.8 mass%	63	80	6
III	Experience 3. Bituminous composition: Bitumen - 69.0 mass% Polyethylene (II) - 4.0 wt% Fuel oil - 27.0 mass%	80	51	4

The results obtained, when they were introduced in Table 3, indicate the softening effect of the secondary polyethylene introduced into the composition of the bitumen composition. At the same time, the softening temperature according to RaB of bitumen compositions obtained with the introduction of 1.4–4% mass of recycled polyethylene into the composition decreases from 110°C to 46-80°C. Moreover, the compositions obtained with a content (% 1.4% by weight) of secondary polyethylene are characterized by a relatively low softening temperature index, which is apparently associated with obtaining a homogeneous composition. Thus, the obtained sample of the bitumen composition is characterized by the best indicator of elasticity at 25°C (13 cm) against 3 cm for the starting material. With an increase in the amount of secondary polyethylene introduced into the bitumen composition, the resulting composition is characterized by a relatively high melting temperature (80 ° C), as well as extensibility (4 cm), which may be due to both compaction of the resulting bitumen composition and heterogeneity.

IV. CONCLUSION

Thus, the conducted research cycle established that the total composition obtained by modification by adding an additive as a softening secondary polyethylene in an amount of 1.4–4.0% and 27–28% by weight of the thinning component of fuel oil has improved indicators, in particular, a relatively high extensibility and the depth of penetration of the needle, and thus ensures the use of this composition under different climatic conditions. The possibility of improving the qualities of oil road bitumen by introducing into it a polymer modifier and a softener is shown.

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