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Improvement of production technology of asphalt concrete with the use of polymer waste

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Abstract. In this study the ROB 70/100 oil asphalt from the Aktau Bitumen Factory «CaspiBitum» was considered. Asphalt was modified with polymer waste to upgrade operating properties. The I-40 industrial oil was used as a softener. Indicators like penetration, extensibility (ductility), brittleness temperature and softening temperature of bitumen were explored in this study. It was shown, that physical-mechanical properties of bitumen increased after modification: needle penetration depth decreased, extensibility decreased, softening temperature increased. In addition, the influence of polymers on the structure of bitumen and the effect of their action in the composition were examined. Structure of polymer waste in Republic of Kazakhstan was analyzed. It was proved, that the usage of the recycled polyethylene as a modifier is a rational approach, and it makes it possible to recycle stocks of secondary polymeric materials. Also problems of improving the properties of polymer-bitumen binder and ecology solved.

1. Introduction

Modern road construction requires high demands on road building materials, especially binders, in particular bitumen for asphalt concrete [1].

One of the promising directions for improving the quality of bitumen is the use of various additives, which include polymer wastes [2-3].

The analysis of the literature shows that the use of polymer waste as a modifier of bitumen can increase its physical and mechanical properties, improve adhesion with mineral components, increase strength, deformation resistance, frost resistance, and water resistance of a road structure [4-6].

However, a sphere of the use of polymer materials as additives in waste in the Republic of Kazakhstan has been studied poorly so far. While asphalt concrete mixtures with the addition of polymers improve the physical and mechanical properties of road asphalt concrete, increase crack resistance at low temperatures and shear resistance at elevated temperatures [7-8]. Therefore, research in the field of improving the physical and mechanical properties of road bitumen using polymer wastes is still relevant.

In connection with the above, the goal of this work is to increase the operational characteristics of oil road bitumen brand ROB 70/100 by modifying it with polyethylene waste.



2. Materials and methods

The following materials have been used for the study: BND 70/100 petroleum road bitumen of the Caspi Bitum Aktau Bitumen Plant, secondary polyethylene (PE) and I-40 industrial oil. Oil road bitumen is a large-capacity oil refining product that has a set of valuable technical properties and is widely used in road construction. Physicochemical properties of this bitumen are shown in the table 1.

Table 1. Physical and-chemical properties of oil road bitumen grade ROB 70/100

Indicator	Value
Needle penetration depth, 0.1 mm:	
- at 25 ° C	70
- at 0 ° C	22
The softening temperature by the ring and ball, ° C	49
Tensile at 25 ° C, cm	71
Fragility temperature, ° C	-21

Secondary polyethylene (PE) has been used as a modifier of road bitumen. The former is a waste of the production of the polyethylene pipe workshop of Ural Commercial and Industrial Company JSC. High-density polyethylene brand PE-100 is employed for the manufacture of the pipes In the workshop, the waste is recycled (on an extruder) to a homogeneous material either in the form of granules or in the form of flakes. The results of conducted studies in the workshop laboratory are given in table 2, from which it follows that secondary polyethylene retains a sufficiently high strength and deformation characteristics and can be used as a modifying additive to bitumen.

Table 2. Physical and chemical properties of primary and secondary polyethylene grade PE 100

Indicator	Primary polyethylene	Secondary polyethylene
Tensile strength, MPa	22-45	10
Elongation at break, %	300-500	220
Frost resistance, °C	-70 and below	-40
Melting temperature, °C	130-135	110
Deconstruction temperature, °C	325	320

Table 3. Characteristics of I-40 oil according to GOST 20799-88

Name of an indicator	Units of measurement	I-40
Density at 20°C	kg / m ³	883,1
Kinematic viscosity at 40 ° C	mm ² / s	65,9
Flash point in open crucible	°C	236
Pour point	°C	-16
Acid number	mg KOH / 1 r	0,006
Ash content	%	0,005

I-40 industrial oil has been used as a plasticizer. The oil, which belongs to the class of general use products and serves not only for use in aggregates of various industries and technical equipment, but also is used as a plasticizer in the preparation of polymer-bitumen binders. The plasticizer reduces the

mixing time of bitumen with the polymer, increases the viscosity and improves the features of the resulting polymer-bitumen binder. The physicochemical properties of industrial oil I-40 are presented in the table 3.

In order to assess the effect of this plasticizer on the properties of bitumen and to determine the required amount for thinning the binder, the plasticizer was introduced in an amount of 0 to 4 %, a further increase was not beneficial from an economic point of view. Then, the softening and fragility temperatures of bitumen were determined (Figure 1).

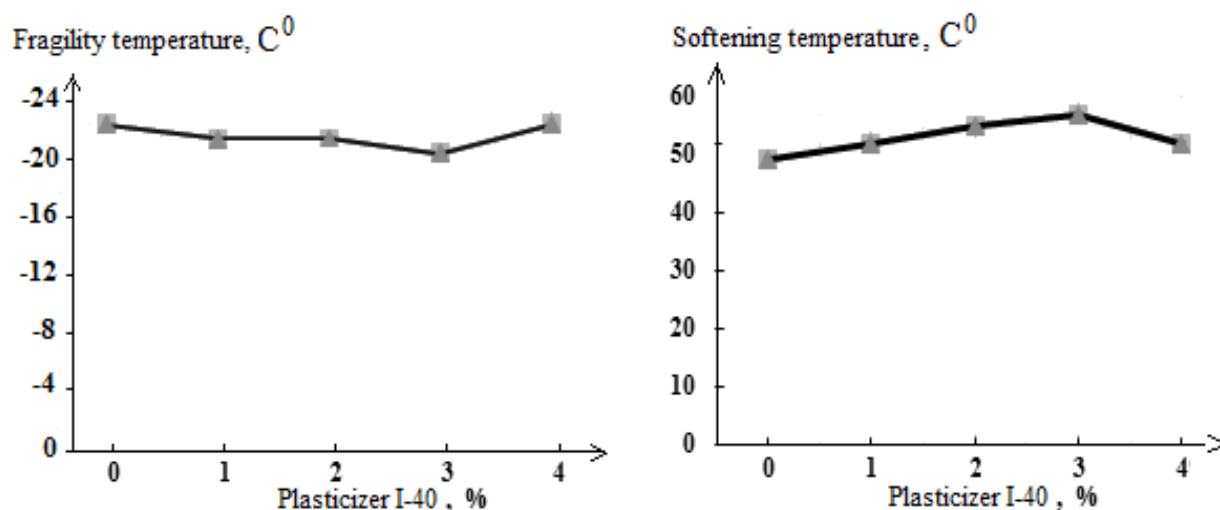


Figure 1. Dependence of softening temperature (a) and brittleness temperature (b) on the content of plasticizer.

As it can be seen from the figure, the I-40 plasticizer has shown the best effect at a content of 3 %, which was used for further selection of the composition of the PBB.

3. The Polymer-bitumen binder preparation method

The required amount of bitumen is loaded into a metal container with a volume of at least 0.5 l, a certain amount of plasticizer is added and heating is turned on and mixed until smooth. At a temperature of 150-160 °C, secondary PE is input in portions into the molten bitumen. First, the mixture is slowly mixed until it is completely wetted and the polymer is uniformly distributed. Then intensive mixing of the mixture with simultaneous gradual heating to 190-200 °C is begun. Mixing is carried out for 30-40 minutes.

The change in the properties of the polymer-bitumen binder was studied at various polymer concentrations: 1, 2, 3, 4 % by weight of bitumen.

4. Results and discussion

The physicochemical parameters of PBB were investigated: depth of penetration of the needle, softening temperature along the ring and ball, extensibility at 25 °C, brittleness temperature. In the table 4 presents the results of studies of the physicochemical parameters of road bitumen and PBB.

As it can be seen from the table 4, the use of a polymer composition leads to an improvement in resistance to constant loads at elevated temperature, which is explained by the presence of a polymer network, increased resistance to cracking with a significant decrease in temperature, enhanced resistance to aging, temperature resistance, hardness and elasticity.

Table 4. Physical and chemical properties of bitumen, modified PE

Indicator	Value				
	0	1	2	3	4
Modifier Number, %	0	1	2	3	4
Needle penetration depth, 0.1 mm:					
at 25°C	70	67	64	61	65
at 0°C	22	24	23	23	23
Tensile at 25 °C, cm	71	47	27	19	49
Softening temperature according to KSh, °C	49	51	55	59	57
Fragility temperature, °C	-21	-21	-21	-20	-22

The studies have shown that by varying the content of the secondary polymer, the required performance properties of bitumen can be achieved. And the use of a plasticizer, in addition to the above indicators, improves the plastic and strength properties of bitumen.

The analysis of the results of studies of road bitumen properties and PBB shows that the use of a polymer composition leads to a significant improvement in most indicators. In particular, the depth of penetration of the needle is reduced by 10 mm at 25 °C. Extensibility is significantly reduced at 25 °C - from 71 to 19 cm. The softening temperature according to the ring-and-ball method increased from 49 to 59 °C, thereby decreasing the tendency of bitumen to deform. The fragility temperature is within the normal range.

In terms of hardness, bitumen binders with a polymer content of 3 % have the best characteristics. Penetration, or penetration depth of the needle, indirectly characterizes the degree of hardness of bitumen.

In terms of the softening temperature of the bitumen binder, samples containing up to 3 % polymer are also optimal, since with a further increase only a slight increase is noticed.

Elongation at 25 °C decreases with the addition of up to 3 % polymer additives, then its increase is observed.

In terms of the combination of physical and chemical and operational characteristics, we conclude that for bituminous binders with a polyethylene content of 2.5-3 %, the most optimal ratio of all indicators is achieved.

Thus, it can be concluded that the improvement of the performance properties of bitumen occurs when 1 % polymer modifiers from secondary PE are already added. However, the maximum result for polymer-bitumen binders is achieved by adding 3 % secondary polyethylene and 3 % plasticizer.

5. Conclusion

The physicochemical properties of road bitumen grade ROB 70/100 were studied before and after modification with polymer waste. The effect of the polymer additive on its operational properties is shown. It is established that the use of polymer waste as a bitumen modifier will solve the environmental problem of environmental pollution by these wastes. Since disposable dishes thrown into landfills or buried, food wraps decompose under natural conditions for at least 100 years. Their contact with rainfall and groundwater is accompanied by leaching of a number of toxic organic compounds (diphenylamine, dibutylphthalate, phenanthrene), flammable (in case of fire, it is quite difficult to extinguish them), when stored, they are a breeding ground for rodents, blood-sucking insects and serve as a source of infectious diseases.

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