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Experimental Study the Modification of Bitumen with Waste Tires

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Abstract

The ever-increasing amount of waste tires creates serious environmental problems. One of the directions for recycling crumb rubber obtained by grinding from worn tires is to obtain rubber-bitumen binders using it, which can be used in road construction, for insulating coatings and in other areas. The use of crumb rubber as a secondary composite raw material in road construction partially solves the problem of saving bitumen, recycling worn-out rubber products and related environmental problems.

Keywords: Modification, bitumen, waste tires, polymer-bitumen binders.

1. Introduction

The increase in requirements for the transport and operational characteristics of asphalt concrete pavements, associated with an increase in traffic speeds and an increase in the number of heavy and super-heavy trucks in traffic on a number of highways, clearly reveals the insufficiency of the currently existing level of quality of road bitumen [1]. Due to the fuel orientation of local oil refining, bitumen produced on the residual principle in its basic properties does not meet the requirements of the more complex operating conditions of roads. In fact, the capabilities of petroleum bitumen as binders for asphalt concrete are being exhausted [2]. For this reason, the service life of road asphalt concrete pavements is reduced, and premature failure of asphalt concrete pavements occurs due to the intensive development of damage in the form of ruts, plastic deformations, peeling, cracks, potholes, etc. Aggressive influence of environmental conditions, technogenic and climatic factors also have a significant impact. Therefore, great importance is attached to the creation and implementation of new complex binders for road asphalt concrete, capable of increasing the service life of roads and their quality [3-5].

Modification of bitumen with various additives makes it possible to change their structure in such a way as to increase the plasticity range, i.e. temperature range in which the binder retains the viscosity necessary to ensure the resistance of asphalt concrete both to defects and damage of a brittle nature such as cracks, potholes, spalling, and to plastic defects, primarily ruts [6].

In particular, the problem of modifying the structure of not only bitumen, but also asphalt concrete arises. Research work in this direction has been carried out for many years [7-9]. Attempts have been made to change the structure of asphalt concrete by introducing into its composition such materials as sulfur, crushed rubber, finely ground rubber powder, rubber granulates, etc. It was found that rubber-like modifiers introduced into the composition of the asphalt concrete mixture have the properties of dampers that reduce the level of tensile and compressive stresses in asphalt concrete pavement under cyclic influences of passing traffic under conditions of variable temperatures. These studies did not find wide application in the road industry; everything ended, as a rule, with the construction of experimental sections, where, as a result of observations, a decrease in the level of crack formation in coatings, including reflected cracks, was noted.

In recent years, there has been a significant revival in the market of road additives and modifiers: various polymers, thermoplastic elastomers, rubbers, rubber crumbs and others. Thanks to these additives, asphalt concrete pavements acquire a number of valuable qualities: their plasticity improves, resistance to temperature influences and reversible deformations, and durability increases.

The use of crumb rubber for modification and bitumen binder showed the promise of its use. Recommended areas of application of rubber-bitumen binders are the

preparation of asphalt concrete mixtures based on rubber-bitumen binders, crushed stone-mastic asphalt concrete, and rough surface treatment devices. Asphalt concrete is recommended for use in the construction of highways of technical categories I and II, city streets, runways, main taxiways, and bridges.

2. Materials and Methods

In the work, commercial petroleum neat bitumen of the road grade BND 100/130 and crumb rubber from the Kazakhstan Rubber Recycling LLP plant (Astana) with a particle size of less than 0.5 mm were used as research objects.

Experiments on the preparation of rubber-bitumen binders were carried out with bitumen grade BND 100/130, the physical and mechanical characteristics of which, in accordance with standards of Kazakhstan 1373-2013: needle penetration depth at 25 ºC – 113, softening temperature (ring and ball method) – 44 °C, ductility at 25 ºC is 150 cm.

SEM images of crumb rubber from the Kazakhstan Rubber Recycling LLP plant (Astana) with a particle size of less than 0.5 mm are shown in Figure 1. The images were taken at the Al-Farabi KazNU National Open Nanotechnology Laboratory of with a Leica DM 6000 M optical microscope using light reflection.

The bitumen was heated to 160-170 °C and crumbled rubber was introduced in portions in an amount of 0.5 wt. %. With constant stirring from 60 to 180 minutes, the temperature of the mixture was brought to 190 °C. Then, after cooling the samples, their physical and mechanical properties were determined.Submit your manuscript electronically for review.

3. Results and Discussion

Table 1 shows the physical and mechanical properties of rubber bitumen binders prepared from road bitumen with the addition of crumb rubber with a particle size of less than 0.5 mm. The indicators are compared with the requirements of technical specifications 5718-004-05204776-01.

Table 1. Physical-mechanical characteristics of rubber-bitumen binders

Indicators	Neat bitumen	Mixing duration, hours					Requirements for technical specifications	
		1	1.5	2	2.5	3	RBB 60/90	RBB 40/60
Penetration at 25°C	113	48	58	61	64	65	61-90	40-60
Softening temperature, °C	44	45	44	46	40.5	44	not lower than 46	not lower than 56
Ductility at 25 °C, cm	150	11.3	14	16.2	17	16.5	at least 12	at least 10

As can be seen from Table 1, with an increase in the amount of added rubber crumb, a decrease in the depth of penetration of the needle is observed, which characterizes the hardness of the material. With increasing mixing time, the softening temperature of rubber-bitumen binder increases, but after 150 minutes of mixing it sharply decreases. This may be due to the rubber crumbs not being completely dissolved during the mixing process. The ductility of rubber-bitumen binders increases, which gives additional plasticity to the obtaining product. These data confirm the gradual compaction of road bitumen with the addition of crumb rubber. Among the prepared samples, only the binder containing 0.5 % crumbs with a mixing time of 120 minutes satisfies the requirements of the specifications for RBB 60/90. Another samples, despite the appropriate values of the softening temperature and the depth of penetration and ductility do not satisfy the requirements of the specifications.

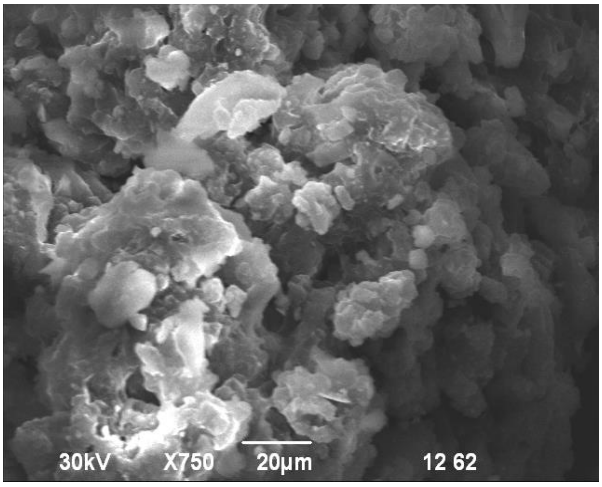

Figure 1. SEM image of waste tires

Electron microscopic studies of waste tires show that the used tire is not distributed in the form of individual particles, but in an interconnected structure. The crumb presents a porous amorphous structure. The effect of bitumen in this composition is similar to the effect of the filler. Such fibrous and layered structures in bitumen give the obtaining product increased strength and elasticity properties.

4. Conclusion

The addition of crumb rubber measuring less than 0.5 mm to petroleum road bitumen leads to an increase in the rigidity of rubber-bitumen compositions, while meeting the requirements of the technical specifications of rubber-bitumen binders RBB 60/90.

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