ABSTRACT

to the thesis for the degree of Doctor of Philosophy PhD on the specialty 6D072100 - Chemical technology of organic substancesof **Alipbekova Zhamilya Kozhageldievna** "Development of technology for the production of polymer-bitumen binders, modified with rubber chips**"**

The relevance of the work. An integral condition for the dynamics of the national economy is the development and maintenance of the effective functioning of the transport infrastructure, which maintains the integrity and continuity of economic interactions. However, the quality of many bituminous materials no longer meets modern requirements. For example, statistical analysis shows that the service life of road surfaces made of bitumen-mineral compositions is only 50-70% of the standard. The indicators of temperature resistance of bituminous materials are also low, which limits the use of products made from them both in the hot summer period and in the winter, especially in areas with a sharply continental climate. Bitumen has low efficiency under conditions of alternating deformation. All these disadvantages lead to a decrease in the durability of materials in which they act as a binder and impregnating component.

The steadily increasing requirements for the quality and performance of bitumen-based materials can no longer be satisfied only by choosing raw materials and improving the bitumen production technology. In this regard, the problem of creating and further improving the quality of road surfaces, taking into account the territorial features of their operation, is an urgent problem.

One of the main radical ways to improve the quality and durability of alphalt concrete pavements is the modification of bitumen with polymer materials. A significant number of used for the regeneration of old automobile tires and the prospects for the development of capacities for grinding rubber create the preconditions for the widespread use of vulcanized crushed rubber in road construction to improve the performance properties of asphalt concrete pavements. All this indicates the need to create new large-capacity bitumen produced in the Republic of Kazakhstan, which, along with the creation of bitumen materials with improved performance properties, will solve the issues of utilizing worn-out rubber tires.

Relations to the research works and government programs. The work was carried out within the framework of the fundamental research program: B-16-03-04 "Development of technology for obtaining elastomeric compositions using local mineral raw materials and technogenic waste" (2015-2020) and B-21-03-03 "Development of new technologies and processes for processing heavy petroleum feedstock to obtain composite materials" (2021-2025).

Research object. Polymer-bitumen binders modified with crumb rubber.

Research subject. The process of obtaining polymer-bitumen binders modified with rubber chips, research and substantiation of the physical and mechanical

characteristics of polymer-bitumen binders based on domestic bitumen BND 70/100 and modified rubber chips of “Eko-Shina” LLP.

Purpose of the research. Development of technology for obtaining polymer-bitumen binders modified with crumb rubber of “Eko-Shina” LLP, obtaining polymer-bitumen binders modified with crumb rubber, formulation with the use of industrial waste, study of the physical and mechanical characteristics of polymer-bitumen binders based on domestic bitumen and local industrial waste production.

Tasks of the research:

-influence of the physical and chemical properties of rubber crumb of “Eko-Shina” LLP on the complex of the main physical and mechanical indicators of polymer-bitumen binders;

- modification of rubber crumb of “Eko-Shina” LLP and study of the regularities of the process of structure formation of bitumen during the formation of polymer-bitumen binders;

- development of formulations and technologies for obtaining polymer-bitumen binders containing modified rubber crumb;

- analysis of factors affecting the physical, mechanical and operational properties of rubber-bitumen binders used to improve the quality of asphalt concrete;

- development of a basic technological scheme for obtaining polymer-bitumen binders modified with crumb rubber from “Eko-Shina” LLP and conclusion.

Scientific novelty of the research.

The following results have been achieved.

-new polymer-bitumen binders based on domestic bitumen used to improve the quality of asphalt concrete with improved operational properties have been determined;

- bitumen binders with modified rubber crumb have been received;

- the patterns of structural changes occurring in the process of obtaining binders modified with crumb rubber by “Eko-Shina” LLP have been established;

- the factors influencing the complex of the main physical and mechanical indicators of the operational properties of the rubber-bitumen binder have been analyzed;

- the features of modifying rubber crumb of “Eko-Shina” LLP with expanded vermiculite have been investigated and the specifics of the formation of the structure of polymer-bitumen binders have been determined;

- the choice of parameters was substantiated and a basic technological scheme for obtaining polymer-bitumen binders modified with rubber crumb “Eko-Shina” LLP was developed;

Practical significance of the thesis. In the dissertation, a technology for obtaining polymer-bitumen binders was developed and a technological scheme was drawn up. Semi-industrial tests were carried out at “Eko-Shina” LLP and “Neftekhimstroy-Yug” LLP. On the basis of industrial waste from the rubber industry and Kulantau vermiculite, formulations of PBB with improved operational properties have been compiled, it is recommended for use to improve the quality of asphalt concrete.

- in the results of the study, the ways were considered that the use of Kulantau expanded vermiculite for modifying rubber crumb in the composition of a polymer-bitumen binder provides an increase in adhesion properties, an expansion of the plasticity interval and an increase in the stability of the properties of PBB during their long-term operation;
- the research materials were registered in the production test certificates.

The main research provisions for the defense:

- physical and chemical properties of rubber crumb “Eko-Shina” LLP used to improve the quality of bitumen and asphalt concrete;
- structural changes occurring in the process of obtaining bitumen binders with modified crumb rubber;
- the analyzed factors influencing the performance properties of the bituminous binder;
- the selected parameters and the developed conceptual technological scheme for the production of polymer-bitumen binders modified with rubber crumb of “Eko-Shina” LLP;
- economic efficiency of production of PBB based on PGB 70/100 bitumen and rubber crumb from “Eko-Shina” LLP;
- results of production tests of polymer-bitumen binders modified with rubber crumb of “Eko-Shina” LLP.

The analytical review considers modern concepts of the structure of petroleum bitumen and polymer-bitumen binders using crumb rubber. As you know, the most versatile material for use as a binder in road paving is petroleum bitumen, due to its ability to withstand the effects of low temperatures, temperature extremes, and various deformation loads without destruction. Currently, 4 plants for the production of road bitumen operate in Kazakhstan, with a total capacity of 1.2 million tons per year. In 2016, the main bitumen production was launched at the Caspian bitumen enterprise. Analysis of the main indicators of the Ministry of Energy of the Republic of Kazakhstan for 2015-2020 showed that the volume of bitumen production has doubled since 2015.

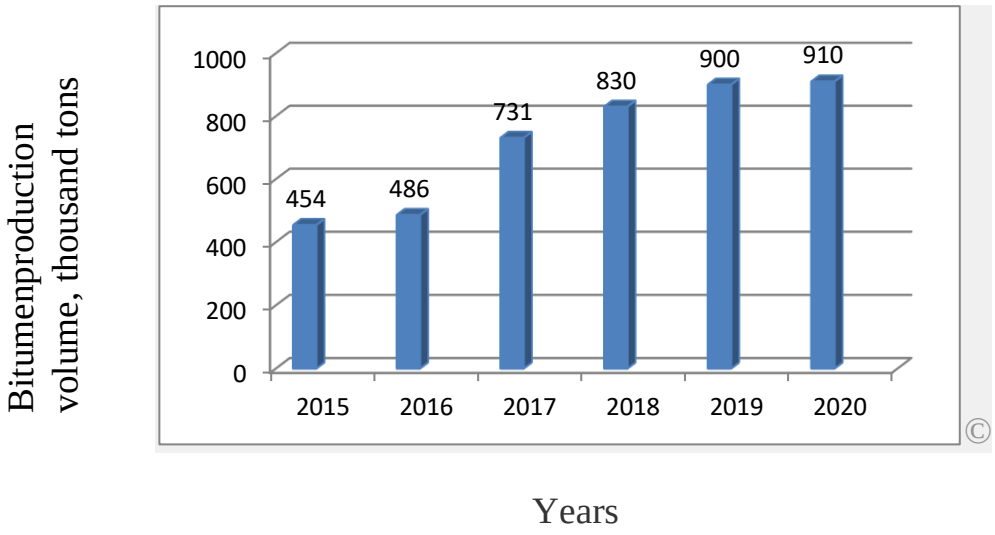

Figure 1 - Development of the bitumen industry in the Republic of Kazakhstan for 2015-2020

It is known that the properties of ordinary unmodified bitumen do not allow obtaining road surfaces with the required set of properties, which is most pronounced at high and low temperatures. The practice of operating road surfaces using viscous road bitumen of the PGB grade indicates that the destruction of the surface begins already in the first year of operation due to the insufficient capacity of the bitumen binder to stretch. The main reasons for the destruction of asphalt concrete in the road surface are climatic conditions, loads from traffic flows, as a result of which aging of bitumen occurs, i.e. it becomes brittle, flakes and cracks.

The most effective methods for creating new materials are based on modifying the binder (bitumen) by introducing additives (modifiers) into its composition that improve its performance properties. It has been found that cost effective modifiers are those that are available and inexpensive. From a technical point of view, to create composite materials based on bitumen with a given set of properties, only those modifiers that do not collapse at the temperature of asphalt concrete mixture preparation can be used; compatible with bitumen when carrying out the mixing process on conventional equipment at temperatures traditional for the preparation of asphalt concrete mixture; do not impart rigidity or brittleness to bitumen at low temperatures in the pavement, and in summer they increase the resistance of bitumen in the composition of the road surface to shear stress and at the same time do not increase the viscosity at mixing and laying temperatures; chemically and physically stable, retain their properties during storage, processing and in the composition of the road surface. Currently, in domestic practice, polymer-bitumen binders (PBB) are obtained by dissolving the polymer in bitumen or by preliminary dissolving the polymer in a special solvent, followed by mixing the polymer solution with bitumen.

Comparison of the effectiveness of different methods of bitumen modification showed that a promising direction for bitumen modification is the use of crumb rubber additives. Rubber crumb is widely used as a component of crack-filling

compounds for road construction, building roofing and various anti-corrosion mastics. The properties of polymer-bitumen compositions (PBC) are determined by the volumetric content and particle size of the dispersed phase - polymer in the bitumen matrix. In cases of small particle sizes, the dispersed phase has a weak effect on the development of irreversible deformations in the material, and with an increase in the particle size of the dispersed phase above the critical value, the composition is prone to delamination. Due to its low solubility, rubber is introduced in a finely dispersed form, which requires additional energy costs for its grinding.
Rubber crumb is a collection of particles of various shapes and dispersion of crushed rubber. The material is characterized by the fact that it basically retains the molecular structure and properties of the original rubber. In this case, the surface of the particles can be changed so as to impart special, predetermined properties to the crumb rubber. These changes can be obtained by partial devulcanization of the upper layer of particles or by chemical, physical or physicochemical treatment.

General view of rubber crumbs of different dispersion are shown in Figures 2-4.

Figure 2 - General view of rubber crumb “Eko-Shina” LLP2-4 mm in size

Figure 3- Rubber crumb produced by “Eko-Shina” LLP in the size of 1-2 mm

Figure 4 - General view of rubber crumb “Eko-Shina” LLP dispersion 0-1 mm

Crumb rubber is obtained by processing worn-out automobile tires and other waste rubber goods. The most large-tonnage resource of used rubber is car tires. Their disposal is a serious environmental problem in many countries.

Numerous domestic and foreign studies and experience of using crumb rubber show that modified binders have higher performance properties than traditional

bitumen. Asphalt concrete based on bituminous binders containing modified rubber crumb are characterized by increased wear and heat resistance, aging resistance, lower rigidity, good sound-absorbing and frictional ability, resistant to water, freezing - thawing.

One of the problems of obtaining rubber-bitumen binders was the choice of the size of the rubber crumb. Analysis of the nomenclature of sizes of rubber crumb produced by "Eko-Shina" LLP showed that manufacturers put up for sale rubber crumb up to 1 mm, 1–2 mm and 2–4 mm in size. It was necessary to determine which of the presented fractions is most suitable for obtaining rubber-bitumen binders. At the same time, such technological parameters as the temperature and preparation time necessary for dissolving the rubber crumb to a size of inhomogeneities not exceeding 0.1 mm were evaluated, as well as the physicochemical parameters of the rubber-bitumen binder, such as the softening temperature along the ring and ball.

Physicochemical indicators of the rubber-bitumen binder, depending on the dispersion of the rubber crumb, are shown in Table 1.

Table 1- Physicochemical indicators of rubber-bitumen binder, depending on the dispersion of the rubber crumb.

No.	Dispersion of rubber crumb, mm	Temperature, ºC	Time, hour	Softening temperature on the ring and ball, ºC
1	less 0,1	185-195	1-1,5	50
2	0,1-1	185-195	1-2,0	50
3	1-2	185-195 200-210	3-3,5	44\17
4	2-4	210-220 235–245	3-3,5	45\25

The experiment shows that the ratio of the maximum size of rubber crumb to the minimum should be as small as possible, since in this case the destruction of rubber proceeds more uniformly, which improves the physicochemical properties of the rubber-bitumen binder, which is confirmed by the spectra of the microstructures of rubber crumb, taken with an electron microscope JSM- 6490LV.

Thus, for further research on the use of rubber crumb of "Eko-Shina" LLP in rubber-bitumen binders, crumb rubber of 0.5-1mm fraction was used.

To study the structure of the materials under study, we used a Shimadzu IR Prestige-21 Fourier Transform Infrared Spectrometer with a Miracle ATR attachment from Pike Technologies. Samples of PGB 70/100, rubber crumb with a dispersion of 0.5-1 mm were selected. Figures 5-7 show the IR spectra of the structures of rubber crumb, the original bitumen PGB 70/100 without the addition of rubber crumb, with the addition of different amounts of rubber crumb 5%, 10%, and the combined IR spectra of bitumen compositions containing different amounts of rubber crumb (from 5 % to 25%).

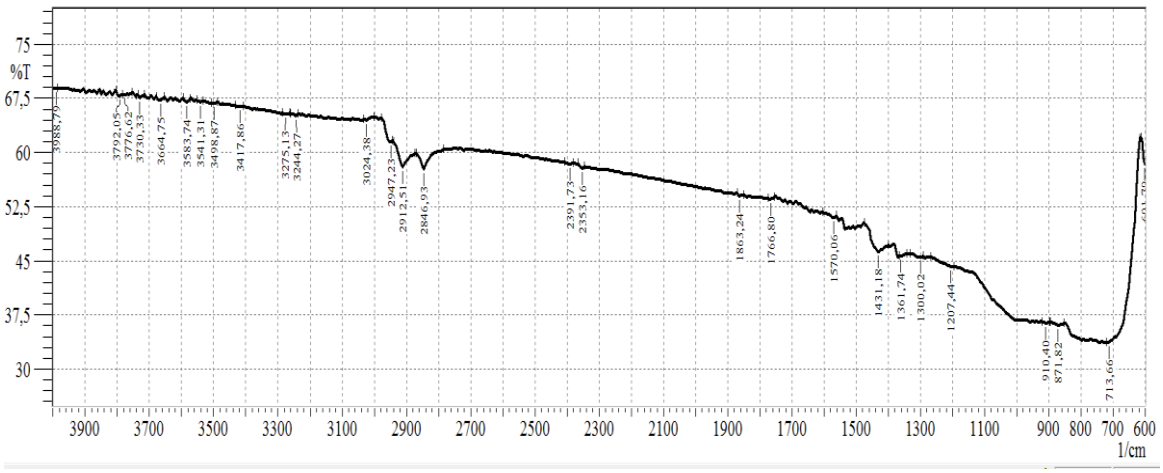

Figure 5 - Spectrum of a sample of rubber crumb “Eko-Shina” LLP with a dispersion of 0.5-1 mm.

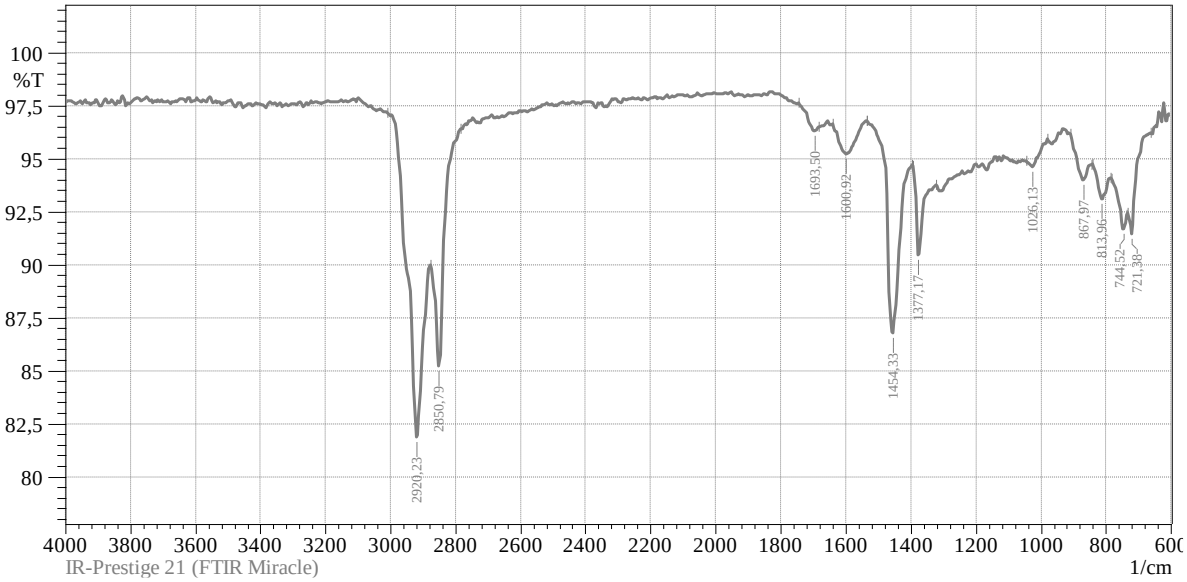

Figure 6 - IR spectrum of PGB bitumen with the addition of 5% crumb rubber

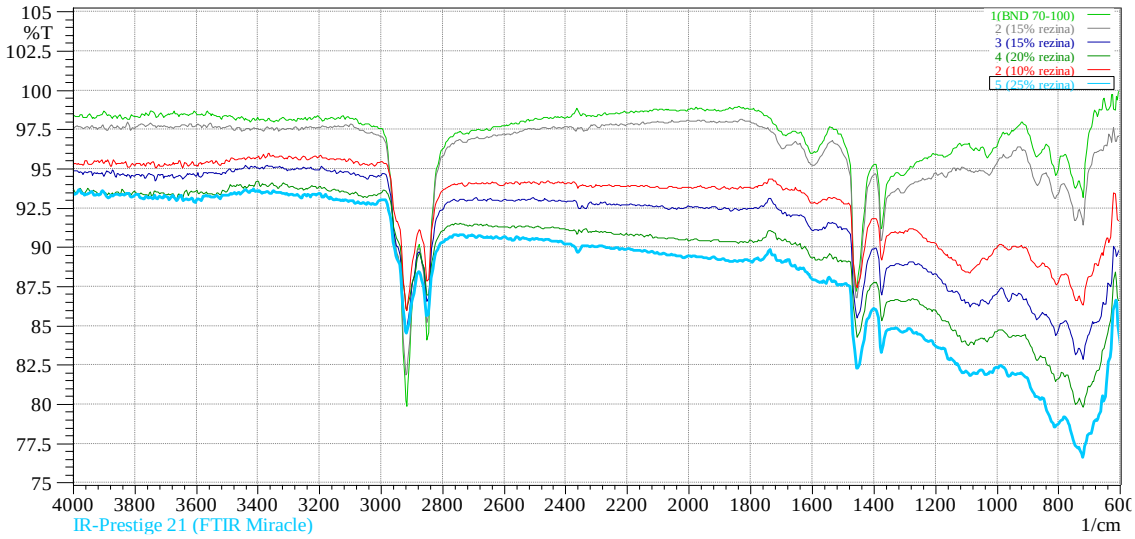

Figure 7 - Combined IR spectra of bitumen compositions containing different amounts of crumb rubber (from 5% to 25%).

The analysis of the obtained results of studies of bitumen grade PGB 70/100 showed the presence of intense bands characteristic of bitumen in the region of 3000-2800 cm^{-1} (valence vibrations of H(CH) and CH_2 groups), 1460 cm^{-1} (deformation vibrations 5 (CH_2)) and 1377 cm^{-1} (deformation vibrations 5 (CH_3). These bands are always present in the spectra of saturated hydrocarbons, paraffins, oils. The spectra of the components clearly show the transmission band at 720 cm^{-1}, which corresponds to the bending vibrations of 5 (CH_2) groups in free paraffin chains. The characteristic triplet of 747, 812, and 870 cm^{-1} is clearly manifested - a sign of the presence of aromatic structures. The technical result of the invention was an increase in the durability of a bitumen-rubber binder with improved rheological characteristics, a significant reduction in cost due to an increase in the service life of the road asphalt pavement.

The physical and mechanical characteristics of bituminous binders containing modified crumb are shown in Table 2.

Table 2 - Physical and mechanical characteristics of bituminous binders containing modified crumb

No.	Indicators	Proposed composition							According to GOST 52056-2003 PBB 60
		1*	2*	3*	4*	5*	6*	7*	
1	Needle penetration depth, 0.1 mm: at 25°C at 0°C, not less	 75 22	 54 18	 52 16	 53 14	 50 19	 52 15	 54 16	 60 32

2	Softening temperature in the ring and ball, ° C	48	50	54	55	56	54	55	54
3	Brittleness temperature, ° C	-20	-13	-9	-12	-10	-13	-11	-20
4	Elongation, cm: at 25°C at 0°C	 65 32	 65 35	 70 28	 80 44	 78 48	 58 56	 60 54	 25 11
5	Elasticity	55	59	63	67	66	63	64	70

*With various contents of crumb rubber and vermiculite

The preparation of the rubber-bitumen binder (RBB) was carried out by mechanical mixing of bitumen with crumb rubber, corresponding to the concentration and temperature of RBB, corresponding to the temperature of the preparation of the asphalt concrete mixture at asphalt concrete plants.

The physical and mechanical properties of RBB were determined using standard methods.

As a result of research carried out at the Department “Oil Refining and Petrochemistry” of M. Auezov SKU” in the period from 2018 to 2021, a new technology was developed for the chemical combination of domestic petroleum bitumen PGB 70/100 with fine rubber crumb, aimed mainly at improving the quality of domestic bitumen, the properties of which do not meet modern operational requirements. When developing the technology, an integrated approach was used, taking into account the physical, mechanical and chemical processes that occur both in the initial bitumen and their mixtures with rubber, and in the final products - asphalt concrete and road surfaces.

The technology is based on the addition of expanded Kulantau vermiculite to the mixture of bitumen with crumb rubber, which in a certain way regulates the processes of destruction and cross-linking of rubber chains of rubber and high-molecular components of bitumen. As a result of the process, rubber particles are combined both with each other and with high molecular weight components of bitumen into a heterogeneous, reinforcing, polymeric spatial structure using chemical bonds. The stability of the entire dispersed heterogeneous system, high and long-term adhesion of the binder is ensured by the polar molecular groups of vermiculite. Due to this structure, the binder acquires elasticity sufficient for operational purposes. The binder becomes resistant to crumb rubber segregation and high (for a short time up to 250°C) process temperatures.

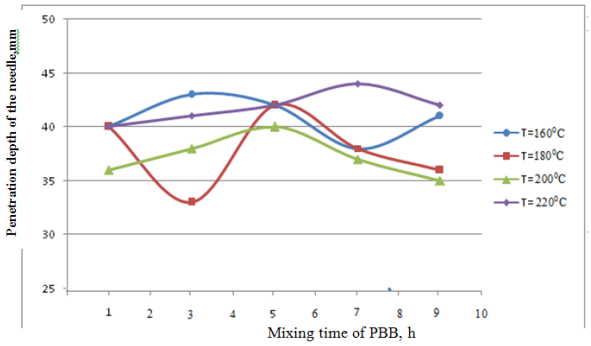

Figure8 - Dependence of the penetration depth of the needle at 25°C on the mixing time of PBB

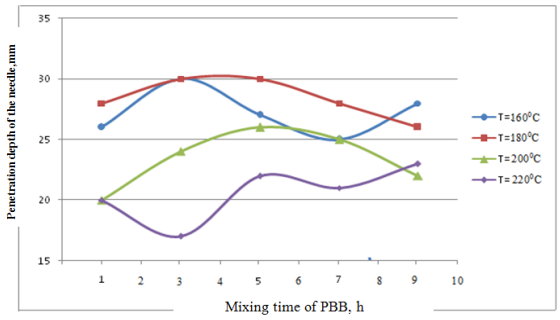

Figure9 - Dependence of the penetration depth of the needle at 0°C on the mixing time of the PBB

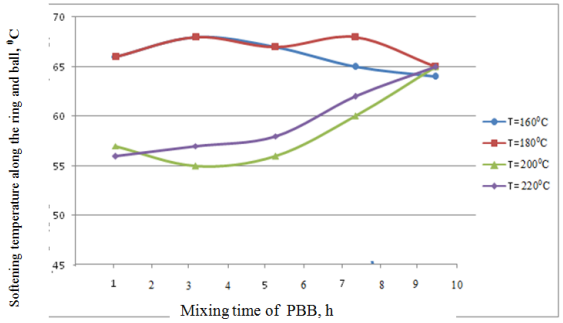

Figure10- Dependence of the softening temperature along the ring and ball on the mixing time of PBB

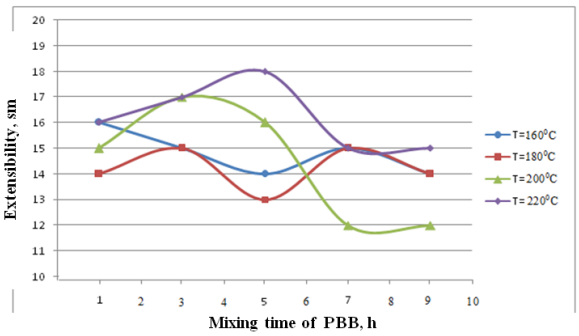

Figure 11- Dependence of the extensibility of polymer-bitumen binders on the mixing time at 25 ° C

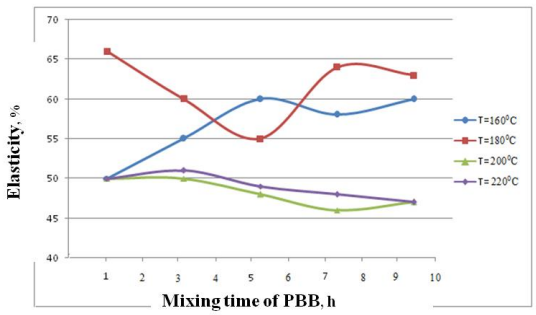

Figure 12-Dependence of the elasticity of polymer-bitumen binders on the mixing time

As a result of the experiments, it was found that at temperatures below 140°C, the dispersion time of crumb rubber in bitumen is more than 4 hours. Within the framework of these studies, this value seems to be the maximum, since with a longer duration of the stage of dispersing crumb rubber, the productivity of the entire process of preparing RBB cannot be considered profitable.5-7 hours of stirring is optimal. The upper value of the experiment temperature is 220°C, due to the fact that thermal destruction of crumb rubber begins to actively proceed.

Figures 8-12 show changes in the main operational characteristics of RBB (depth of penetration of the needle, at 0°C and 25°C, softening temperature along the ring and ball, extensibility and elasticity), prepared depending on the mixing time in the temperature range 150-220°C in the mixer.

The main reasons for these changes are bitumen oxidation and the effect of high temperature on crumb rubber. Oxidation of light components of bitumen, such as resins and oils, leads to an increase in the softening temperature of the samples and a decrease in penetration. The original structure of the modified rubber crumb changes, and its chains are crosslinked along multiple bonds. This negatively affects the elasticity of the resulting product.

Thus, the optimal temperature for RBB preparation is a temperature in the range of 150-170°C. It should be noted that with a reduction in the duration of mixing of the components with a simultaneous increase in the process temperature in the polymer-bitumen binder, processes occur intensively in which the performance of the binder changes. It can be noted that the correct determination of the temperature regime allows you to save working time and energy resources, increase the productivity of the installation and in the best way realize the potential of crumb rubber as a highly effective bitumen modifier.

The technology is based on the addition of expanded Kulantau vermiculite to the mixture of bitumen with crumb rubber. As a result, rubber particles combine both with each other and with high-molecular-weight components of bitumen into a heterogeneous, reinforcing, polymeric spatial structure using chemical bonds. The stability of the entire dispersed heterogeneous system, high and long-term adhesion of the binder is ensured by polar molecular groups introduced in large quantities into the structure of the material during its preparation. Due to this structure, the binder acquires elasticity sufficient for operational purposes. The binder becomes resistant to crumb rubber segregation and high (short-term up to 250°C) technological temperatures.

The processing technology is based on mechanical crushing of tires to small pieces, followed by mechanical separation of metal and textile cords, based on the principle of “increasing fragility” of rubber at high impact speeds, and obtaining fine rubber powders up to 0.5-1 mm in size by extrusion crushing of the resulting rubber crumbs.

The technological process includes three stages: preliminary cutting of tires into pieces; crushing rubber pieces and separating metal and textile cords; obtaining finely dispersed rubber powder.

The technological scheme for the preparation of a polymer-bitumen binder modified with crumb rubber from “Eko-Shina” LLP is shown in Figure 13.

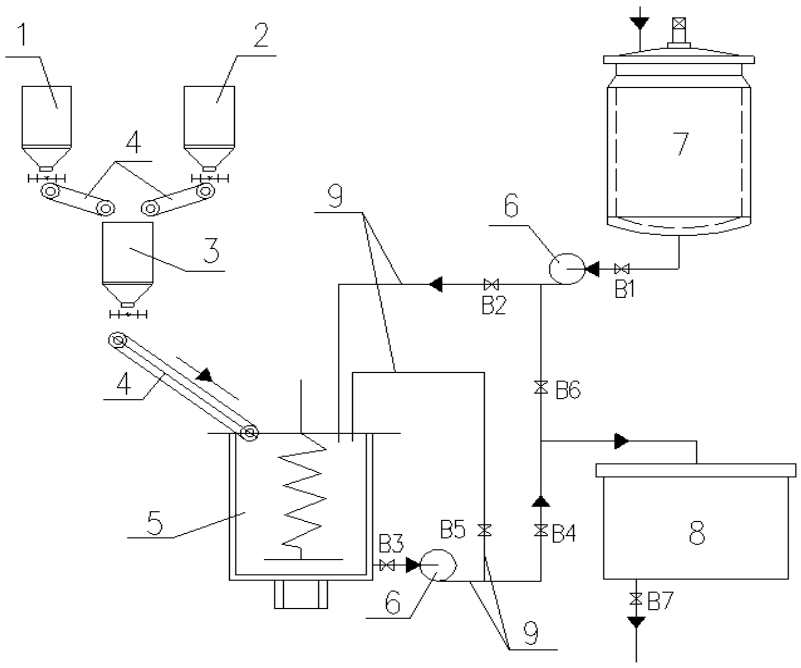

Figure 13 - Technological scheme for the preparation of polymer-bitumen binder modified with crumb rubber of“Eko-Shina” LLP

1-bunker-batcher of rubber crumb, 2- bunker-batcher of vermiculite, 3- bunker-batcher of modified rubber crumb, 4- conveyor belt, 5- screw-blade mixer, 6- bitumen pumps, 7- bitumen boiler, 8- storage tank, 9 - pipeline

B1, B2, B3, B4, B5, B6, B7 - valves for shutting off pipes to change the direction of flow of bitumen or mixture.

Bitumen (70-76 mass%), heated to operating temperature in a bitumen boiler 7, is fed by pump 6 into a screw-blade mixer 5. Rubber crumb of “Eko-Shina” LLP(18-22 mass%) comes from a rubber crumb metering hopper 1 into bunker 3. from where also from the bunker 2 comes the expanded Kulantau vermiculite in the amount of 6-8 mass%. The rubber crumb modified with expanded vermiculite from the hopper 3 through the belt conveyor 4 enters the screw-blade mixer 5. The temperature and duration of mixing depend on the type and properties of rubber crumb and bitumen. The modified rubber crumb of “Eko-Shina” LLP is mixed with PGB 70/100 bitumen at a temperature of 150 - 170°C for 5 - 7 hours. Additional mixing of the polymer-bitumen binder is carried out due to the circulation of the binder by the pump 7. Then the polymer-bitumen binder is fed through the pipeline 9 to the storage tank 8.

Thus, on the basis of domestic bitumen, a technology has been developed for the production of polymer-bitumen binders modified with crumb rubber with high performance properties, which can be used in the construction and repair of highways.

Pilot production works were carried out on the territory of “Neftekhimstroy-Yug” LLP and “Eko-Shina” LLP. On the UIS-2U impact grinding installation with a capacity of up to 2 tons per hour, a pilot batch of a mixture of modified crumb and sand (in a ratio of 1:2 by weight) in an amount of 1000 kg was produced. Then the

resulting mixture in an amount of 3% by weight of the mineral parts were introduced into the asphalt concrete mixture. In March 2021 tests of asphalt pavement cuttings were carried out. The results of the pilot production studies are shown in Table 4.

Table 4 - Results of pilot testing of polymer-bitumen binders modified with crumb rubber of“Eko-Shina” LLP

List of property indicators	Test results		Value according to GOST 9128-97 for asphalt concrete pavements
	asphalt pavement cutting (used)	asphalt pavement cutting (proposed)	
Compressive strength, MPa at temperatures, °C:			
20	4,4	10,6	No less 2,2
50	1,41	1,95	No less 1
0	10,8	11,7	No more 12
Water saturation,% by volume	1,29	1,27	1,5-4,0
Water resistance coefficient after prolonged water saturation	0,92	0,98	0,75

The tests carried out have shown that in terms of their sanitary and hygienic properties, these binders are cleaner than bitumen and meet the most stringent environmental requirements. Rubber crumb in the binder acts as particles of the polymer component, which carry out dispersed-elastic reinforcement of asphalt concrete.

The experimental and production work carried out at “Eko-Shina” LLP showed a significant advantage of asphalt concrete based on such bitumen-rubber binder with modified rubber crumb of domestic production in the arrangement of the upper layers of coatings in comparison with traditional hot asphalt mixtures. Testing the test plots showed a significantly better condition compared to neighboring plots made using unmodified bitumen. Asphalt concrete pavements are in good condition, there are no damage to the pavement, cracks, confinement, and binder bleeding. The adjacent control areas are damaged in the form of a network of small cracks, peeling of the surface, stains, and secretion. The total area of which is more than 10% of the total coverage area.

Due to the improved characteristics of the binder, the service life of asphalt concrete pavements prepared using polymer-bitumen binder modified with crumb rubber from **“**Eko-Shina**”** LLP is on average 2-3 times higher than the service life of pavements using road bitumen under the same operating conditions, due to the higher crack resistance, water resistance and strength of the resulting asphalt concrete. Such coatings reduce the level of noise and vibration, reduce the possibility of ice crust formation, increase traction, and shorten the braking distance. The properties of the binder make it possible to successfully arrange durable thin-layer wear-resistant coatings and some types of surface treatments. Thus, the developed technology makes it possible to obtain polymer-bitumen binders with a wide range of properties that can be used in the construction and repair of highways.

CONCLUSION

1. To solve the problems of the quality of road surfaces in Kazakhstan, it is necessary to develop new materials based on bitumen, capable of providing a higher strength, durability of road surfaces in comparison with the fundamental capabilities of oil bitumen. Analysis of modern concepts of the structure of petroleum bitumen and polymer-bitumen binders showed that a promising direction for modifying bitumen is the use of crumb rubber additives. In this regard, based on local materials and man-made waste from used tires an effective technology for the production of rubber-bitumen binders has been developed.

2. On the basis of the main provisions of the theory of oil dispersed systems, the principles of effective modification of polymer-bitumen binders using crumb rubber are formulated. For the first time, the physicochemical properties of rubber crumb of "Eko-Shina" LLP, used to improve the quality of bitumen and asphalt concrete, have been investigated and the optimal dispersion and amount of rubber crumb in the composition have been investigated and established. The validity and reliability of the results obtained is confirmed by the use of modern research methods - a JSM-6490LV scanning electron microscope with energy dispersive microanalysis and structural analysis systems and Shimadzu IR Prestige-21 Fourier Transform Infrared Spectrometer for studying the structures of polymer-bitumen binders.

3. To improve the technological properties of crumb rubber (caking during storage), the effect of expanded Kulantau vermiculite on the properties of polymer-bitumen compositions for road use was first investigated. As a result of the interaction of bitumen with a material having a high specific surface area and a fine-pored structure, the group composition of bitumen changes due to the selective diffusion of oils and resins into the material, which leads to a change in the properties of bitumen layers on the surface of particles and the formation of strong bitumen films on the surface of grains. The use of Kulantau vermiculite in the composition of a polymer-bitumen binder provides stable adhesion in a wide temperature range, an increase in the specific surface area, which acquires additional energy capacity, which leads to an increase in the degree of adhesion to bitumen. A characteristic feature of PBB is increased strength in the entire range of the investigated temperatures with the introduction of expanded vermiculite. The choice of expanded Kulantau vermiculite is also determined by the availability and relative cheapness. The composition "Modified rubber crumb" has been developed and protected by a patent for a useful model, which makes it possible to obtain high-quality polymer-bitumen binders.

4. Structural changes occurring in the process of obtaining bituminous binders with modified rubber crumb have been investigated. Modification of bitumen with crumb rubber leads to changes in the frequency of valence H (OH) in the high-frequency part: the intensity increases, and the maximum shifts from 3344 cm^{-1} (bitumen spectrum) to 3440 cm^{-1} (modified bitumen). This change is associated with some restructuring in the structure of the hydrogen bonds of bitumen when it is introduced with crumb rubber. A characteristic absorption band of the carbonyl group, which in the spectrum of modified bitumen shows the concentration of free radicals, which are

one of the factors that determine the tendency of asphaltenes to associate intermolecular interactions that promote the formation of supramolecular structures.

5. Analysis of factors affecting the performance properties of rubber-bitumen binder showed that at elevated temperatures destructive processes prevail in rubber crumb, which, depending on the temperature and duration of mixing with bitumen, can lead to complete destruction of rubber.

6. Experimental and production work carried out at “Neftekhimstroy-Yug” LLP and “Eko-Shina” LLP showed a significant advantage of asphalt concrete based on a new bitumen-rubber binder with modified rubber crumb of domestic production in the construction of top layers of coatings in comparison with traditional hot asphalt mixtures. Thanks to the improved characteristics of the binder, the service life of asphalt concrete pavements prepared with the use of polymer-bitumen binder modified with rubber crumb “Eko-Shina” LLP on average, 2-3 times higher than the service life of pavements using road bitumen under the same operating conditions, due to the higher crack resistance, water resistance and strength of the resulting asphalt concrete.

7. Parameters have been selected and a technological scheme has been developed for obtaining rubber-bitumen binders using modified rubber crumb to create road surfaces of the required quality, allowing to reduce the cost of binders and environmental stress in the region. Correct determination of the temperature regime - the optimal temperature for the preparation of RBB - the temperature in the range of 150-170°C and the mixing time of 5-7 hours, allow you to save working time and energy resources, increase the productivity of the installation and in the best way to realize the potential of modified rubber crumb as a highly effective modifier of bitumen.

Evaluation of the economic efficiency of the production of polymer-bitumen binders modified with crumb rubber by “Eko-Shina” LLP showed that the production is profitable and economically viable. The economic effect of the production of rubber-bitumen binders modified with crumb rubber by “Eko-Shina” LLP
is 7 991 491.2 KZT per year.