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DEVELOPMENT OF COMPOSITION AND PRODUCTION TECHNOLOGY FOR POLYMER-BITUMEN MIXTURES FOR AUTOMOBILE ROADS

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Abstract: This article highlights that the modification with varying amounts of organomineral modifier primarily improves parameters that lead to an increased service life of road bitumens, as supported by data obtained from experimental studies. It has been established that the softening and freezing temperatures of the polymer-bitumen composition are altered by adding thermomechanically ground powder of worn-out rubber products based on styrene-butadiene and isoprene rubbers. This addition is made at high temperatures, utilizing active organic compounds present in the modified bitumen.

Keywords: Polymer-bitumen composition, freezing point, melting point, penetration, organomineral modifier, sand, resistant to shear and compression, crushed powder, elasticity, extensibility, heat resistance, and crack resistance.

Introduction. Currently, scientific research is being conducted to create and produce polymer-bitumen compositions for the construction of roads in the automobile road industry. These compositions are aimed at developing roads that meet all requirements, have a long service life, withstand variable climatic conditions, and possess improved technological, rheological, physical-mechanical, and dynamic properties[1-2]. In this regard, the development of classified compositions of asphalt concrete mixtures adapted for use in various conditions for road paving and extending their service life is of great importance. This includes developing technologies for obtaining and using these compositions, as well as selecting and creating modifiers, organic and inorganic ingredients to be included in the mixture. Today, in the world and in our country, technologies for obtaining and modifying bitumen, preparing organic and inorganic ingredients and raw materials for the production of asphalt concrete pavements for road surfaces have been developed, and the composition, production, and use of bitumen compositions based on them, used in various conditions, have been introduced [3-4].

The object and methods of the study. The objects of the research were waste products from oil and gas processing, metal enrichment, and the rubber industry, as well as road bitumens of grades BND 40/60, BND 50/70, BND 60/90, and BND 90/130. The elastic-strength properties of the composition were determined according to GOST 270-2015, cold resistance according to GOST 408-2013, and abrasion resistance according to GOST 23509-2014. The study of the properties of bitumen and rubber-bitumen composites was conducted in accordance with GOST 4333-2014, while the investigation of the strength and deformation properties of asphalt concretes was carried out in accordance with GOST 12801-2013.

Results and discussion. It is well known that in the rapidly changing weather conditions of the Republic of Uzbekistan, the performance properties of bitumens currently used in road construction do not meet the required standards. Taking this into account, a study was conducted on the influence of an organomineral modifier, created from local raw materials, on the main indicator of the technological process for preparing bitumens BND 40/60, BND 50/70, BND 60/90 and their compositions used in road construction. Specifically, the effect on the mixing temperature was examined (Figure 1).

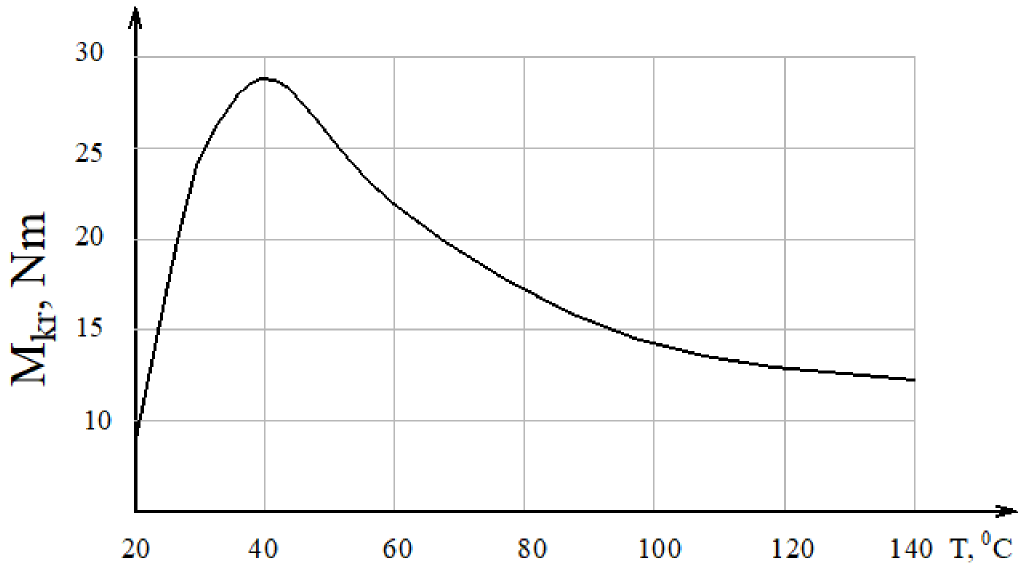

Figure 1. Effect of the organomineral modifier on the mixing temperature of road bitumen

Based on the results of scientific research, it was demonstrated that mixing the organomineral modifier with road bitumen at 200°C yields good results. The following data were obtained from studying the operational properties of the modified BND 40/60 bitumen (Table 1).

As can be seen from the table, the developed organomineral modifier has a positive effect on the operational properties of the selected road bitumens. Specifically, it increases their main indicators such as softening point, reduces freezing point, and enhances ductility and elasticity. As a result, it has been possible to obtain a modified bitumen that meets the requirements of the rapidly changing weather conditions in our republic [4-5].

As we know, the bitumen composition used in road construction is multi-component, with each additive playing a specific role in its operational properties. Taking this into account, a composition was developed based on the requirements for road surfaces using modified bitumen, considering the weather conditions of different regions in the republic. In developing this composition, it was proposed to add thermomechanically ground powder from worn-out rubber products based on butadiene-styrene and isoprene rubbers to the modified bitumen composition. This addition aims to increase its resistance to abrasion, frost, heat, and cracking.

Table 1. Effect of modifier quantity on bitumen properties

Bitumen grades	**Modifier number**	**Modifier amount, wt.%**	**Softening temperature, °C**	**Freezing temperature, Fraas, °C**	**Needle penetration depth, 0°C, 0.1 mm**	**Needle penetration depth, 25°C, 0.1 мм**	**Extensibility, 0°C, sм**	**Extensibility, 25°C, sм**	**Elasticity, 0°C, %**	**Elasticity, 25°C, %**
BND 40/60	**-**	**-**	**59,35**	**-22,4**	**12,5**	**40**	**7,6**	**24**	**21**	**33**
Modified BND 40/60	1	3	65,44	-23,5	12,0	40	8,4	25	21	33
Modified BND 40/60	1	6	71,28	-25,1	11,5	38	9,0	25	24	35
Modified BND 40/60	1	9	82,13	-25,8	11,0	37	9,5	26	27	37
Modified BND 40/60	2	3	68,14	-23,9	11,1	39	8,8	26	22	34
Modified BND 40/60	2	6	76,18	-26,1	10,8	37	9,8	28	26	36
Modified BND 40/60	2	9	84,16	-27,2	10,1	36	10,3	30	28	37
Modified BND 40/60	3	3	70,12	-24,2	10,0	38	9,8	29	22	35
Modified BND 40/60	3	6	78,38	-26,6	9,8	36	10,4	34	27	37
Modified BND 40/60	3	9	86,28	-27,8	8,9	35	12,0	36	29	39

Studies have shown that adding thermomechanically ground powder of worn-out rubber products based on butadiene-styrene and isoprene rubbers to the composition created technological problems in obtaining a homogeneous mixture. To achieve the intended goal, a step was introduced to the technological process: soaking the thermomechanically ground powder of worn-out rubber products based on butadiene-styrene and isoprene rubbers in modified bitumen at a specific temperature for a certain period of time (Fig. 2).

As can be seen from the figure, for the swelling and dissolution of thermomechanically ground powder from aged rubber products based on butadiene-styrene and isoprene rubbers, the technological process temperature should be 200°C, the swelling time 2-3 hours, and its optimal content in the composition 40 wt.%.

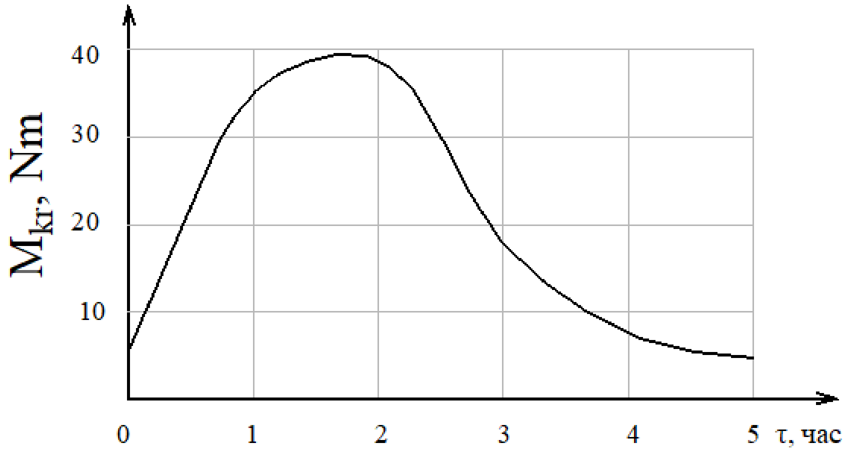

Figure 2. The effect of thermomechanically ground powder from worn-out rubber products based on butadiene-styrene and isoprene rubbers on the preparation time of a composition based on modified bitumen

In this process, at high temperatures, the thermomechanically ground powder of worn rubber products based on butadiene-styrene and isoprene rubbers swells due to active organic compounds in the modified bitumen composition. As a result of breaking the remaining vulcanization networks, additional active centers are formed. This leads to an improvement in the operational properties of the composition. We will examine the influence of organomineral modifiers and ingredients used in the development of polymer-bitumen compositions for road surfaces on the technological and physical-mechanical properties of the composition. Studies have shown that the softening temperature of the composition depends on the amount of organomineral modifiers and ingredients added to the mixture (Figure 3).

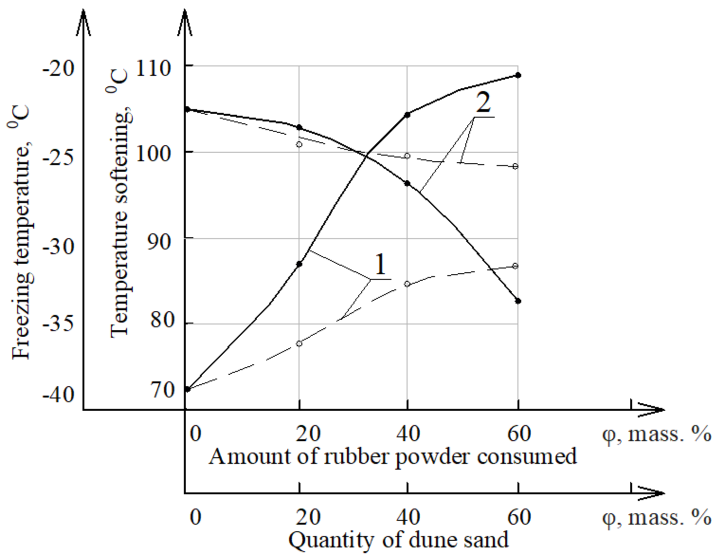

Figure 3. The effect of thermomechanically ground powder (____) from worn rubber products and Fergana barchan sand (----) on the softening (1) and freezing (2) temperatures of the polymer-bitumen composition

As evident from the curves in the figure, the softening temperature of the polymer-bitumen composition increases with a rise in the content of organomineral modifier, thermomechanically ground powder of worn rubber products, and Fergana barchan sand. Studies have shown that the thermomechanically ground powder of worn rubber products can increase the softening temperature of the polymer-bitumen composition by 1.5-2 times. This is primarily because the vulcanization networks, which underwent devulcanization under the influence of thermomechanical forces, begin to re-vulcanize under the heat exposure during the technological process. In this process, -S-S-S- and -S-Sn-S- bonds are formed, resulting in improved physical and mechanical properties of the polymer-bitumen composition (Figure 4).

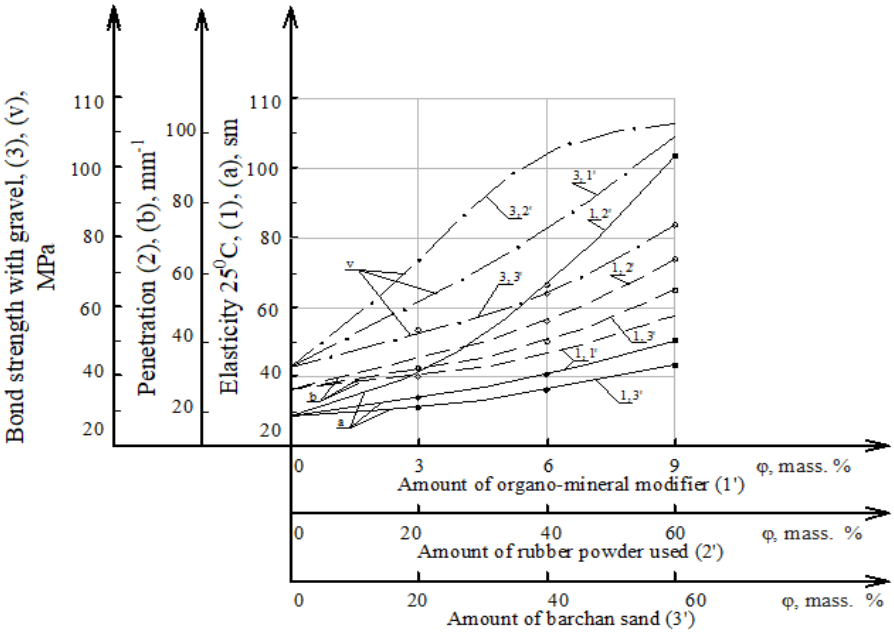

Figure 4. The influence of organomineral modifier, powder obtained through thermomechanical grinding of old rubber products, and the amount of Fergana barchan sand on the adhesion strength, penetration, and tensile strength at 25°C of the polymer-bitumen composition with mineral raw materials

As evident from the figure, the adhesion strength, penetration, and expansion at 25°C of polymer-bitumen compositions with mineral raw materials increase as the amount of proposed ingredients increases. This allows for the selection of a composition suitable for the climatic conditions of our republic. Similar results were observed in all three proposed organomineral modifiers.

As is known, one of the main problems on highways is the settlement and displacement of asphalt concrete pavement on roads frequented by heavy trucks and in front of traffic lights. It has been determined that due to the vulcanization networks formed in the proposed polymer-bitumen coating, the occurrence of settlement and displacement on the roads is reduced (Fig. 5).

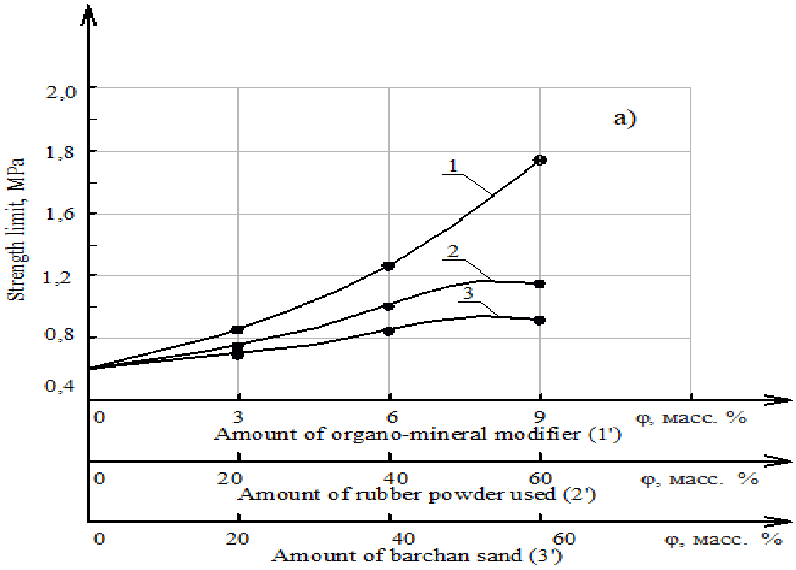

Figure 5. The effect of organomineral modifier, thermomechanically ground powder of used rubber products, and the amount of Fergana barchan sand on the shear (a) and compressive (b) strength of the polymer-bitumen composition

As evident from the figure, the compressive strength of the compositions increases with the rise in the amount of organomineral modifier, thermomechanically ground powder of worn-out rubber products, and Fergana barchan sand, with values ranging from 5.2 to 6.4 MPa [6-8]. The maximum compressive strength was observed at a 1:2 ratio of modified bitumen to thermomechanically ground powder of worn-out rubber products. Additionally, as the amount of thermomechanically ground powder of worn-out rubber products in the Fergana barchan sand composition increases, the shear strength limit also rises, allowing for the selection of compositions based on climatic conditions [9-10].

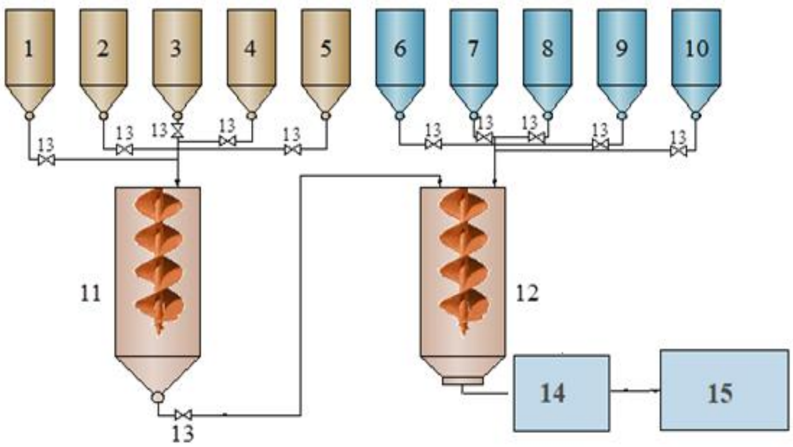

Figure 6. Technology for preparing polymer-bitumen composition.
1-modified bitumen, 2-powder from thermomechanically ground worn rubber products, 3-Fergana barchan sand, 4-gravel, 5-clinker, 6-10-targeted additives, 11-melting reactor, 12-mixer, 13-pumps, 14-disperser, 15-vehicle.

Based on the obtained scientific results, mineral fillers are added to the recommended composition in a 1:1 ratio, and the mixture is prepared according to the following technological process (Figure 6).

As shown in the figure, in the technological process of preparing the polymer-bitumen composition, the modified bitumen is melted in reactor 11 at 200-220 °C for 30 minutes. Then, thermomechanically ground powder of worn-out rubber products is added to it in a 1:3 ratio, and for 2 hours, the process of breaking down the non-devulcanized vulcanization networks in the powder is carried out. The prepared semi-finished product is transferred to mixer 12, where at a temperature of 200-220 °C, Fergana barchan sand is added to its composition in a 1:1 ratio to the total volume and stirred for 20 minutes. Then, gravel, clinker, and targeted additives are added to the composition as required and stirred for 30 minutes. The prepared composition should be applied at the desired location within 4 hours. The technology for laying the composition on roads remains unchanged.

Conclusion. It is known that the service life of bitumen compositions can be extended by increasing their resistance to external environmental factors, as well as improving their technological, rheological, physical-mechanical, and dynamic properties. To enhance these characteristics, it is advisable to modify road bitumens and optimally select the type and quantity of ingredients in the polymer-bitumen composition.

Research has shown that for swelling and dissolving thermomechanically ground powder of worn-out rubber products based on butadiene-styrene and isoprene rubbers, the optimal technological process parameters are: temperature of 200°C, swelling time of 2-3 hours, and optimal content in the composition of 40 wt.%. The softening temperature of the polymer-bitumen composition can be increased 1.5-2 times by incorporating thermomechanically ground powder of worn-out rubber products. This is mainly due to the fact that vulcanization networks, which underwent devulcanization under the influence of thermomechanical forces, begin to re-vulcanize under the heat of the technological process. As a result, it was found that with an increase in the amount of thermomechanically ground powder from worn-out rubber products and Fergana barchan sand in the composition of the organomineral modifier, the compressive strength of the compositions increases, and its value can reach up to 5.2-6.4 MPa.

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