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STUDY OF OBTAINING AN ORGANOMINERAL MODIFIER FROM LOCAL RAW MATERIALS TO IMPROVE THE OPERATIONAL PROPERTIES OF BITUMEN

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Abstract: This article presents information on the physicochemical properties of the selected raw materials based on local materials and the technology for obtaining an organomineral modifier from it. To modify road bitumens and increase the resistance of road pavements obtained on their basis to rapidly changing weather conditions, technological, rheological, physical-mechanical, and deformation effects, as well as to increase their wear resistance, ingredients based on local raw materials were selected, their physicochemical properties were studied, and a technology for obtaining an organomineral modifier based on them was developed.

Keywords: Structure, organomineral, physicochemical properties, resistance to shear and wear, ingredient, modification, technological, rheological, kinetics, strength, technology, composition.

Introduction. In road construction worldwide, bitumen-based asphalt concrete composite pavements are widely used, and the requirements for these pavements are increasing with the advancement of mechanical engineering. At the same time, it is necessary to develop classified compositions of asphalt concrete pavements based on specified requirements by modifying bitumen-based mixtures with new materials and ingredients. This approach aims to enhance the structure and characteristics of roads, increase the durability of pavements, and improve the quality of their application.

In this regard, developing technology for producing asphalt concrete composite coatings using local raw materials is of particular importance.

Today, scientific research is being conducted worldwide and in our country's road infrastructure sector on creating ingredients and raw materials for producing modified polymer-bitumen compositions. These compositions are used for paving modern highways that meet international standards. The research focuses on modifying these materials, formulating compositions based on specified requirements, and developing technologies for their production and application in road surfacing [1-4].

The object and methods of the study. The objects of the research are waste 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 was assessed in accordance with GOST 408-2013, and wear resistance was measured as per GOST 23509-2014. The investigation of bitumen and rubber-bitumen composite properties was conducted in accordance with GOST 4333-2014, while the examination of strength and deformation characteristics of asphalt concrete was carried out in compliance with GOST 12801-2013.

Results and discussion. It is well known that our Republic experiences rapidly changing weather conditions, which consequently leads to the quick deterioration of asphalt concrete road surfaces. The main reason for this is that the road bitumens of grades BND 40/60, BND 50/70, BND 60/90, and BND 90/130, which form the basis of the composition used in these materials, are unable to withstand rapidly changing weather conditions (Table 1). Ingredients based on local raw materials were selected to modify road bitumens and enhance the resistance of resulting road surfaces to rapidly changing weather conditions, technological, rheological, physical-mechanical, and deformation-related shear and wear. The physicochemical properties of these ingredients were studied, and a technology for producing an organomineral modifier using them was developed.

Table 1. Physico-chemical properties of road bitumens

Bitumen grades	Softening temperature, °C	Freezing temperature, Fraas, °C	Needle penetration depth, 0°C, 0.1 mm	Needle penetration depth, 25°C, 0.1 mm	Extensibility 0°C, cm	Extensibility 25°C, cm	Elasticity at 0°C, %	Elasticity at 25°C, %
BND 40/60	59,35	-22,4	12,5	40	7,6	24	21,05	33,3
BND 50/70	58,5	-24,8	31	50	10,4	30,7	5,7	18,6
BND 60/90	47	-15	20	61-90	3,5	55	4	13

Cubic residue of gas pyrolysis resin. At the "Uz-Kor Gas Chemical" joint venture for polymer production, tar-product - gas pyrolysis resin - is generated as a waste product. It is a black, odorless solid substance. The composition of gas pyrolysis resin primarily consists of alkanes, dienes, olefins, cycloalkanes, and arenes formed during the pyrolysis process of natural gas. Its molecular mass is approximately 1000-1200, and its melting point ranges from 120 to 180°C. It is known that there is a requirement for the flash point of ingredients used in bitumen compositions to be not less than 184°C. Therefore, we subjected the tar product to thermal treatment at 200-240°C for 120 minutes, during which its quantity decreased by up to 45%, resulting in the formation of a black liquid substance with a molecular mass of approximately 800-1000. The composition of the obtained substance was studied by examining it using IR spectroscopy (Fig. 1) [5].

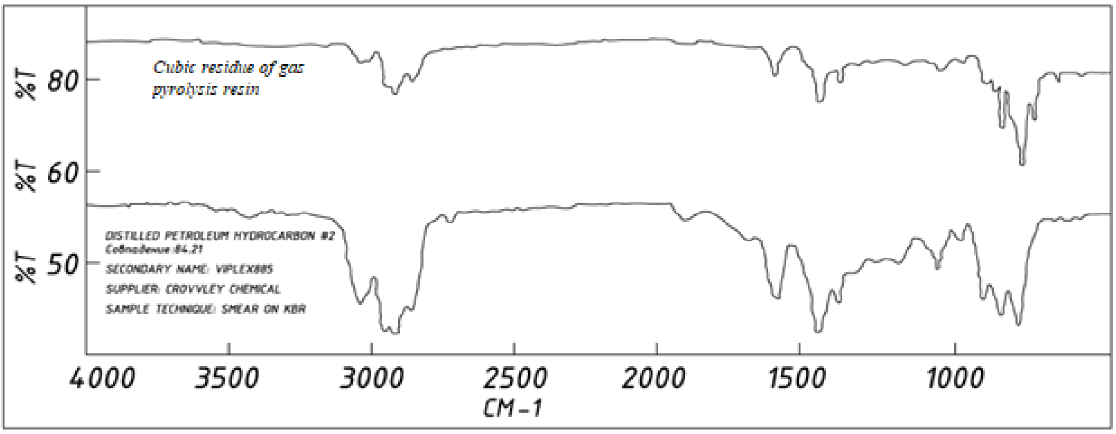

Figure 1. IR spectrum of the cubic residue of gas pyrolysis resin

As can be seen from the figure, its structure is similar to that of the dibutyl phthalate plasticizer, which provides a basis for its potential use in modifying bitumen compositions.

Copper enrichment plant waste. When the composition of copper enrichment plant waste was studied, the following elements were identified: Cu - 0.527%, S - 0.801%, Mg - 0.802%, Zn - 1.45%, Ca - 1.69%, K - 2.15%, Al - 4.56%, SI - 17.8%, Cl - 0.122%, Ti - 0.242%, Cr - 0.0377%, Mn - 0.204%, As - 0.0126%, Rb - 0.0226%, Sr - 0.0131%, Y - 0.0017%, Zr - 0.214%, Mo - 0.223%, Ag - 0.0013%, Sn - 0.0055%, Sb - 0.0468%, Ba - 0.123%, Ir - 0.0145%, Pb - 0.322%. It was hypothesized that these elements increase the activity of the organomineral modifier.

Thermomechanically ground powder of worn rubber-technical products. It is well-known that the problem of recycling worn-out rubber products is currently urgent. Therefore, powdered rubber products were selected as the main ingredient for obtaining organomineral modifiers (Table 2). As can be seen from the table, the properties of the selected ingredient are sufficient for use in the composition and it is recommended to use it in this state.

Table 2. Properties of thermomechanically ground powder from worn rubber products

Name of indicators	Properties
Particle size, μm	50 – 140
Density, g/sm^3	1,200 – 1,250
Bulk density, g/sm^3	4,30 – 4,50
Specific surface area, cm^2/g	1100 – 2200
pH index	7 – 8
Oil absorption, ml/100 g	90 – 100

Butadiensterol rubber. It was used as an ingredient to increase the elasticity, cold resistance, and wear resistance of the composition in obtaining an organomineral modifier for the modification of bitumen. The effect of each selected ingredient on specific properties of the organomineral modifier was determined, and based on the obtained results, an optimal composition and production technology were developed. From the studies conducted, the following compositions of the organomineral modifier were recommended (Table 3).

Table 3. Composition of the created organomineral modifier

Name of Ingredients	Sample 1	Sample 2	Sample 3
	Amount of ingredients, 100 weight units		
Cubic residue of gas pyrolysis resin	82,0	77,0	65,0
Copper enrichment plant waste	5,0	3,0	7,0
Thermomechanically ground powder of worn rubber-technical products	10,0	15,0	20,0
Butadiensterol rubber	3,0	5,0	8,0

It is proposed to use the first sample in the table for modifying bitumens used in desert zones, the second for general zones, and the third for mountainous zones. The created organomineral composite modifier is suggested to be obtained through the following technological process (Figure 2) [6-7].

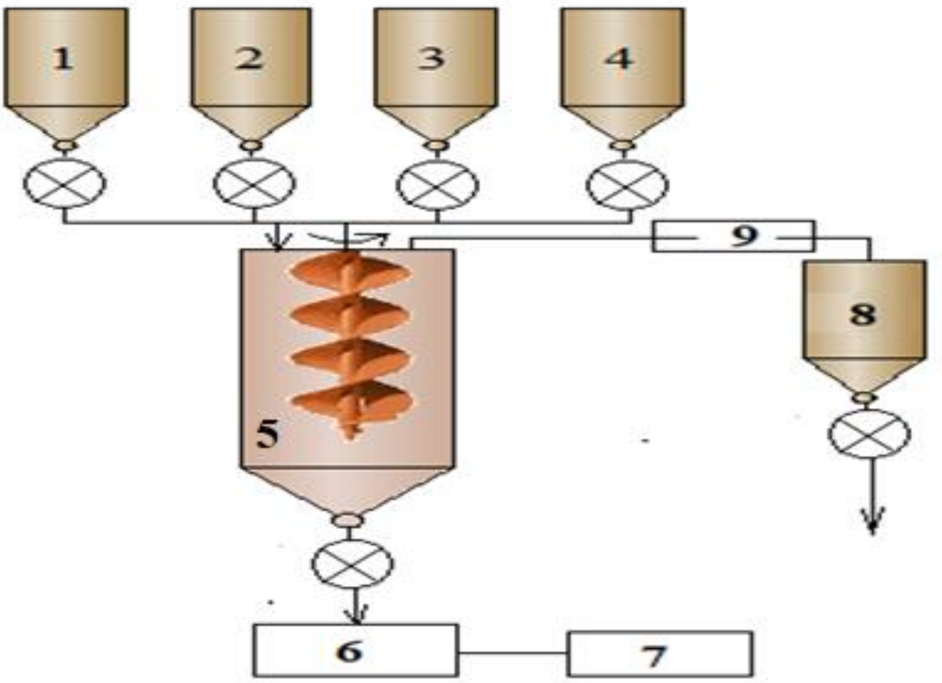

Figure 2. Technological process of obtaining organomineral modifiers
1-4-raw material bunkers, 5-reactor, 6-disperser, 7-packaging machine, 8-condensate hopper, 9-cooler

In this process, the ingredients are ground and meet the GOST requirements for moisture content. Gas pyrolysis resin in powder form is loaded into reactor 5 from hopper 1 and heat-treated at 200-240°C for 120 minutes. Then, ground butadiene-styrene rubber is added from hopper 2 and mixed for 5 minutes. Next, thermomechanically ground powder of worn-out rubber products is added to the reactor from hopper 3 and mixed for 10 minutes. Afterwards, copper enrichment plant waste is added from hopper 4 and mixed for 3 minutes. The composition is then transferred to disperser 6, where it is further mixed for 3 minutes before being sent to packaging machine 7 [8-9]. The physicochemical properties of the resulting organomineral modifier are shown in Table 4.

Table 4. Physicochemical properties of the organomineral modifier

Name of indicators	Sample 1	Sample 2	Sample 3
Appearance	black	black	black
Viscosity (VN-5006, weight 1.5 kg)	1,10	1,15	1,18
Softening temperature, °C	85	89	93
Melting temperature, °C	183	185	191
Freezing temperature, °C	-22	-26	-33
Density, g/cm^3	1,0-1,1	1,1-1,2	1,2-1,3
Adhesion strength, MPa	0,74	0,82	0,84

As evident from the table, changes in the composition's properties were observed when varying amounts of butadiene-styrene rubber, thermomechanically ground powder of aged rubber products, and copper enrichment plant waste were added. This primarily demonstrates that during the thermomechanical grinding of aged rubber products, a devulcanization process occurs in the particles under the influence of thermomechanical forces. Consequently, active centers are formed, leading to the hypothesis that these active centers undergo a certain degree of chemical reactions with the metals present in the copper enrichment plant waste [10-11].

Conclusion. It is well-known that one of the main disadvantages of asphalt concrete compositions is their brittleness in cold conditions and their tendency to become slippery when heavy trucks travel on them in hot conditions. It has been determined that this improvement can be achieved primarily by enhancing the properties of organominerals used in the modification of road bitumens. Therefore, the composition of the organomineral modifier was developed using new local raw materials in this research work. Studies were conducted on three different compositions of the proposed organomineral modifier, which included thermomechanically ground powder of old rubber products, cubic residue of gas-pyrolysis resin, copper enrichment plant waste, and butadiene-styrene rubbers in various proportions. It was determined that the adhesion strength of the proposed organomineral modifier increased by 11.9% when adding different amounts of rubber to its composition. The thermomechanical grinding of worn-out rubber products with an organomineral composition resulted in a decrease of the freezing temperature to -11°C, while also leading to an increase in the softening temperature by 10°C. It is known that the quality of organominerals is determined by their main characteristics such as viscosity, softening point, freezing and melting temperatures, density, and adhesion strength. As a result of the studies, three compositions of organomineral modifiers were recommended. It was proposed to use the first sample for modifying bitumens used in desert zones, the second for general zones, and the third for mountainous zones. Based on the results of our research work, the second sample was implemented in practice.

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CONTENTS

CHEMICAL SCIENCES

TECHNICAL SCIENCES: MECHANICS AND MECHANICAL ENGINEERING

ADVANCED PEDAGOGICAL TECHNOLOGIES IN EDUCATION