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Physical and Mechanical Properties of Composite Materials Filled with Mechanoactivated Ingredients, Applied for Roads, Bridges and Aerodromes

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ABSTRACT: The article presents the results of studies of the first developed effective compositions of composite materials filled with mechanically activated natural sands and other ingredients, which allow increasing the strength properties, heat resistance, shear stability and cracking resistance and, in general, the working capacity and durability of asphalt composite coatings of roads, bridges and airfields.

KEYWORDS: Physical and mechanical properties, heat resistance, composition, fillers, mechanical activation of ingredients, shear stability, crack resistance, performance, durability, asphalt concrete compositions.

I. INTRODUCTION

In the Republic of Uzbekistan, great state, strategic and economic importance is attached to the technical condition of the transport network. In the general transport system of the Republic of Uzbekistan, the dominant position is assigned to roads, along which up to 90% of national economic goods and up to 95% of passengers are transported from the total volume of traffic carried out by all modes of transport. The road network of the republic, including bridges, is more than 147 thousand km, of which 50.7 thousand km are roads with asphalt concrete, concrete surfaces and 96.3 thousand km with oil-mineral and crushed stone surfaces. In the future, it is planned to build reinforced concrete roads with a length of more than 10,000 km, passing through the desert and mountain regions of the republic. There are 11 airfields in the republic with a total area of 600 hectares, covered with concrete and asphalt concrete.

The sharply continental climatic conditions of Central Asia significantly affect the condition and service life of asphalt-concrete roads. The durability of the use of asphalt concrete and oil-mineral road surfaces in Uzbekistan due to their insufficient shear stability at high positive summer temperatures, and cracking resistance at low negative winter temperatures usually does not exceed 2-3 years. [1]. В последние годы широкий интерес представляет создание и получение высокоэффективных композиционных асфальтобетонных покрытий дорог, мостов и аэродромов.

Research by several scientists has created road-building composite materials that can be operated in the temperature range from -30^0C to + 70-80^0C. However, these compositions and mastics do not fully meet the requirements of the climatic conditions of the Republic of Uzbekistan and Central Asia as a whole due to the low melting temperature of bitumen, a decrease in adhesive interactions in the mineral-bitumen system, the formation of ribs and cracks on the surface of asphalt concrete and mastic.

In the world literature, it is extremely insufficiently illuminated and there is practically no information on the study of the possibility of increasing the heat resistance, shear stability and crack resistance and, accordingly, the durability of composite asphalt concrete pavements of roads, bridges and airfields. This is primarily due to the lack of a scientifically substantiated approach to the creation of thermal, frost, and cracking resistant compositions with improved technological properties. The solution to this problem requires a fundamentally new approach to the selection of ingredients, taking into account their polyfunctionality, through preliminary mechanical activation of their surface, which improves the

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surface interaction between the filler and the dispersion medium, leading to the formation of various kinds of semi structures in the bitumen-polymer composition. [4-6].

In this regard, research on the creation and production of import-substituting and export-oriented high-performance composite materials based on mechanically activated and chemically modified ingredients from local and secondary raw materials of organic and mineral origin for asphalt concrete pavements and sealing mastics for filling expansion joints of concrete and cracks in asphalt concrete roads, bridges and aerodromes in order to improve their heat-frost-resistant, shear-resistant and crack-resistant properties and, accordingly, increase the service life in the temperature range from -25^0C to + 120^0C is a very urgent problem.

II. PURPOSE OF THE STUDY.

Creation of effective compositions of import-substituting and export-oriented composite materials with high physical, mechanical and operational properties for asphalt concrete road paving, capable of operating in a wide temperature range from -25 to + 120^0C, based on local mineral and secondary raw materials of organic and inorganic origin**.**

Object and research methods. The objects of research are bitumens of grades BN-90/10 (BNI-V), BN-70/30 (BNI-IV), BND-60/90, rubber crumb, gossypol resin, hydrolyzed lignin, secondary polyvinyl chloride, slaked lime, basalt fibrous filler and activated fine-dispersed wollastonite, Chinaz and Chirchik river, Yazyavan and Yangiyer sands and compositions based on them. [1-2].

The subject of the study was the establishment of physicochemical regularities of the interaction of components of model mixtures and multiphase compositions from organic, modified and mechanically activated mineral and secondary raw materials; determination of the mechanism of mechanical activation of mineral ingredients; investigation of the physical, mechanical and operational characteristics of the developed composite materials for asphalt concrete pavements and sealing their expansion joints and cracks.

III. MATERIALS AND METHODS

Physicochemical properties were investigated using an IR spectroscope. Physic mechanical properties of the composition: -the softening temperature was determined by the Kish method; - brittleness temperature according to Fraasu method; -extensibility according to GOST 11056; - strength of adhesion to concrete according to TshRUz 04/14/2004; - the depth of penetration of the needle according to GOST 11501, water absorption according to GOST 26589. [1].

Research results and their discussion. Let us consider the results of studies of physical, mechanical and operational properties and the development of effective compositions for asphalt concrete road surfaces using organic, modified and activated inorganic ingredients based on local and secondary raw materials.

Based on the results of physicochemical studies of modified bitumen and gossypol resin for creating compositions of asphalt concrete road surfaces, we have developed bituminous compositions, the composition and properties of which are shown in tables 1 and 2. [3].

Table 1. Developed formulations of bituminous compositions based on ingredients from local raw materials recommended for use in road surfaces

Nameofingredients	Contentmass.h		
BitumenBN-60/90	40	40	40
Gossypolresin	35	35	35
Secondarypolyvinylchloride	20	23	
Recycledpolyethene	23		
Hydrolyticlignin	5		
Slakedlime	2	2	
Total:	100	100	100

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Table 2.Physic-mechanical properties of the developed bitumen compositions based on local raw materials and industrial waste

The name ofindicators	Indicatorvalues		
Softening point, 0C, not lower (GOST 11505-66)	82	79	81
Brittleness temperature according to Fraas, 0C, (GOST 11507-65)	-20	-22	20
Elongationat 25 0C, cm,	4.2	4.1	4.0
notlower (GOST 11505-65)	0.29	0.79	0.30
Bond strength to concrete, MPa (GOST 11508-65)	30.0	28.0	32.0
Depth of needle penetration at 25 ° C, mm-1 (GOST 11501-65)	0.18	0.20	0.21

The mechanical properties of asphalt concrete compositions mainly depend on the particle size distribution, the degree of mechanical activation of fillers and the properties of binders.

With this in mind, we have conducted studies of the properties before and after mechanical activation of inorganic ingredients on various equipment.

Studies on the mechanical activation of dune and river sands have shown that the most effective equipment is a dismembrator activator. It was found that the degree of grinding and mechanical activation of ingredients of mineral origin are significantly influenced by such parameters of the dismembrator as the gap between the rotor and the stator, the degree of loading, and especially the speed of rotation of the rotor.

Based on the totality of the studies carried out on the influence of the rotor speed, the gap between the rotor and the stator, as well as the degree of loading of the dismembrator, the optimal parameters for mechanical activation of the natural river and dune sands can be taken as rotor speed of 1500 rpm; the gap between the rotor and the stator - 0.20 mm; loading degree - 3 kg/min., at which the required dispersion and the corresponding specific surface area of the river and dune sands are achieved, and which meet the requirements for raw materials when obtaining asphalt concrete pavements. The mechanism of mechanical activation during the processing of minerals and natural sands in a dismembrator installation is as follows. In the shock-abrasive mode of processing, the activation occurs mainly due to the formation of new surfaces with a slight change in the granulometric composition, and when processing in the shock-splitting-abrasive mode, the activation occurs both due to a change in the granulometric composition and due to the exposure of new surfaces. Studies of the effect of mechanical activation on the properties of natural sands have shown that after mechanical activation of both river and dune sands, their physical properties change significantly, and thus they are significantly activated.

IV. RESULTS AND DISCUSSION

For the development of sealing mastics, highly dispersed particles with a more developed specific surface are required. In this regard, the influence of the speed of rotation of the rotor of the dismembrator on the degree of grinding of wollastonite concentrate was studied. The data obtained show that when processing wollastonite concentrate on a dismembrator unit with a rotational speed of the working bodies of 2900 rpm, a significant increase in its dispersion and, accordingly, the specific surface area is achieved. This, in turn, leads to the production of finely ground mechanically activated wollastonite concentrate. So, if the original wollastonite concentrate contains up to 63.3% of particles with a particle size of more than 200 microns, then during mechanical activation with a rotation speed of the working bodies of 2900 rpm, these particles are crushed to a level below 200 microns and the number of particles with sizes from 100 up to 1 micron, which is 95.4% of the mass of the original wollastonite concentrate. In the process of mechanical activation, the anisotropy coefficient of wollastonite particles approaches unity, and oil absorption values increase from 3 to 12 mg / 100 g, which indicates a noticeable increase in the specific surface area of wollastonite concentrate after mechanical activation in a dismembrator unit?

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a)

b)

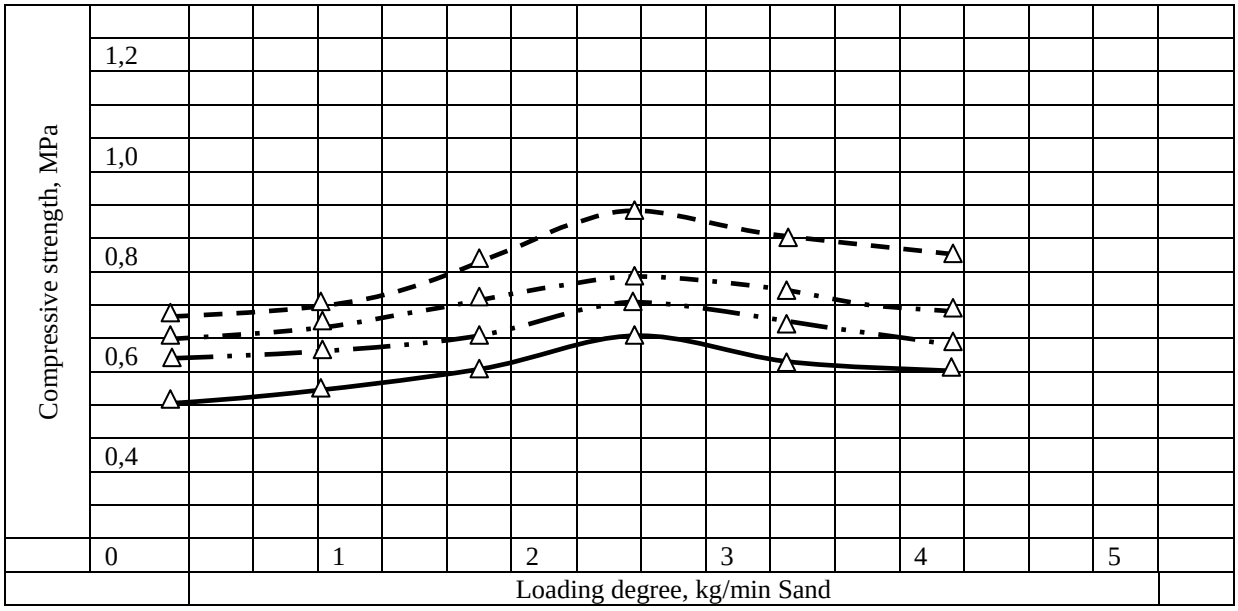

Figure: 1 Dependence of the ultimate strength in compression (a) and shear (b) of asphalt concrete pavements on the degree of loading of the dismembrator during mechanical activation

Thus, during mechanical activation of natural sands on a dismembrator installation under the influence of a shock-splitting-abrasive effect, the activation occurs not only due to an increase in the specific and adsorption surface of dispersed particles but also due to the formation of reactive active centres that contribute to the improvement of

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interphase interactions, which have a significant effect on the physical and mechanical properties of compositions for asphalt concrete road surfaces.

In light of the above, we have studied the effect of mechanical activation of fillers on the strength characteristics of the composition for asphalt concrete pavements, in particular, the dependence of the ultimate strength in compression on the degree of loading of the dismembrator during mechanical activation of sands and the effect of mechanical activation on the strength of the composition for asphalt concrete pavements in shear (Fig. 1 a, b).

It can be seen from the data in the figure that when using mechanically activated sands, a significant increase in the compressive and shear strength of asphalt concrete pavements is observed. When sand is loaded up to 3 kg/min, the compressive strength increases from 1.3 to 3.9 MPa, the shear strength increases from 0, 6 to 1.0 MPa, respectively.

Based on comprehensive studies and the revealed patterns of the results obtained, an effective component of composite materials was developed using mechanically activated natural sands and organic ingredients for asphalt concrete pavements of highways, bridges and airfields.Table 3 shows the optimal compositions of the developed formulations of asphalt concrete pavements.

Table 3.Composition formulations for asphalt concrete pavements

Asphaltconcretepavementcomposition	GOST 9128-97	The developed compositions, wt. %, with a sand content			
		Chirchik	Chinaz	Yazyavan	Yangiyer
Bitumen BND 60-90	6	-	-	-	-
Bitumen BND 60-90 + GS (7% by weight of bitumen)		6,042	6,042	6,042	6,042
Crushedstone	45	45	45	45	45
Non-activatedsand	41	41,058	41,058	41,058	41,058
Mineralfiller	8	-	-	-	-
Mechanicallyactivatedsand	-	8	8	8	8
Total	100	100	100	100	100

Comparative characteristics of the physical and mechanical properties of the developed asphalt concrete pavements are given in the table. 4.

Table 4.Comparative characteristics of physical and mechanicalproperties of the developed compositions for asphalt concrete pavements

Indicators	GOST 9128-97	Mix rates for dense hot asphalt concrete			
		Chirchik	Chinaz	Yazyavan	Yangiyer
Porosity of mineral composition,% by volume, for mixtures of types:					
G, nomore	22	21	21	18	18
D, nomore	22	20	20	19	19
Water saturation,% by volume, for mixtures of types:					
G	1,5-4,0	2,5	2,6	2,0	2,1
D	1,0-4,0	2,0	2,2	1,9	2,0
Residualporosity,% volume	2,2-5,0	3	3,1	3,5	4,0
Compressive strength, MPa, at temperatures:					
+ 20°C, notless	2,2	3,8	3,5	3,0	3,0
+ 50°C, not less, for mixtures of types:					
D	1,2	1,8	1,71	1,58	1,6
D	1,3	1,9	1,8	1,64	1,61
0oC, nomore	12,0	9,0	8,85	7,91	8,0
Water resistance coefficient, not less	0,85	0,90	0,89	0,90	0,88

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From the data in Table 4, it can be seen that compositions for asphalt concrete pavements obtained using mechanically activated sands modified with gossypol resin, in place of a mineral filler, from bitumen BND 60/90 in all physical and mechanical characteristics fully meet the requirements of GOST 9128-97.

V. CONCLUSION

For the first time, a scientifically grounded approach to the creation of heat-frost-resistant, shear-resistant and crack-resistant composite materials based on local and secondary raw materials for asphalt concrete pavements and sealing expansion joints and cracks of concrete, asphalt concrete roads, bridges and airfields with improved physical, mechanical and operational properties is proposed, capable of operating in extreme climatic conditions of the Republic of Uzbekistan.

A new effective method has been developed to improve the physical and mechanical properties of asphalt concrete pavements by introducing mechanically activated mineral ingredients into their composition, in particular, natural river and dune sands, based on the shock-splitting-abrasive effect, leading to the formation of particles with a developed specific surface with the required geometric and physical parameters due to the polarization of particles at the molecular level, accompanied by the appearance of heterogeneous dipole moments, which improve the adhesive properties with the formation of hydrogen bonds with both catatonically active and anionically active substances, such as gossypol resin and, ultimately, an increase in the interfacial interactions between ingredients and bitumen.

On the basis of the revealed regularities, several grades of asphalt-concrete composite materials for road surfacing have been developed - BK-Z-ChchRP, BK-3-ChzRP, BK-3-YazVP, BK-3-YanVP, differing from each other by the nature of the mechanically activated sands used. For each specified brand of the developed composite materials, the optimal technological modes of obtaining them have been determined (heating temperature 150-180^{0}C, mixing time 180 seconds, the temperature of the mixture when discharging from the mixer within 120-155^{0}C and temperature of the mixture at the beginning of laying 110-120^{0}C), providing necessary physical, mechanical and technological characteristics.

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