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Research of Physical-Chemical and Mechanical Properties and Development of Effective Composite Materials Compositions for the Production of Asphalt Concrete Highway Coverings

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Abstract: This article presents the results of studies of the compositions and physical-chemical properties of selected bitumens, rubber powders and other organic-mineral ingredients based on local raw materials, the possibility of improving the physical-chemical properties of bitumens by modifying fine rubber powders and other organic-mineral ingredients.

Keywords: : composite materials, coatings, asphalt concrete materials, elastic-deformation-shear-resistant.

Research methods: *The work used standard physical and mechanical research methods, in particular, determination of compressive and shear strength, needle penetration depth -* penetration*, adhesion strength to concrete, water absorption and other physical and mechanical indicators of composite asphalt concrete materials in accordance with the requirements adopted in the CIS State Standard.*

Research results: *The developed bitumen-polymer asphalt concrete composition for road pavements fully meets all indicators of physical and mechanical characteristics and even exceeds the requirements of technical specifications TU (*Technical *conditions)*

Conclusion. *It has been established that the introduction of fine rubber powders into bitumen-polymer compositions makes it possible to purposefully regulate the structure and* increase *the elastic-strain characteristics of composite asphalt concrete materials and, accordingly, the resulting road surfaces.*

Introduction. Currently, on a global scale, the dominant position is given to roads, along which 90% of national economic goods and more than 95% of passengers from the total volume of traffic carried out by all types of transport are transported. Therefore, special attention is paid to the creation of elastic-, deformation-, shear- and crack-resistant composite materials that improve the quality of highways and improve the technical condition of the transport network and the development of transport communications [1,2,3,4,5].

All over the world, based on organic-mineral ingredients of polymer binders and local raw and secondary resources, research is being conducted to create effective components, composite polymer and asphalt concrete materials and to develop technologies for their production. For this purpose, research is being conducted to study the structure of composite polymer materials and coatings made from them and their physical and chemical properties, to substantiate the influence of the composition, type and quantity of organic-mineral fillers on the physical, mechanical and operational properties of composite and asphalt concrete materials, to develop and organize technologies for their production for construction highways, bridges and airfields that meet modern requirements and ensure durability during their operation [6,7,8,9,10].

It should be noted that, despite the sufficiency of raw materials, the resulting elastic-deformation-shear-resistant asphalt concrete materials do not sufficiently meet the relevant requirements for highways today [11,12,13,14,15,16].

In this aspect, the development of elastic-deformation-shear-resistant composite asphalt concrete materials for road surfaces by physical and chemical modification of organic-mineral components from local and recycled raw materials is an urgent problem today.

Methodology

This study employed a comprehensive methodological approach to ensure an in-depth analysis of the research topic and to draw scientifically grounded conclusions. Both theoretical and empirical methods were applied in an integrated manner. In the theoretical stage, relevant scientific literature, monographs, academic articles, and previous studies were analyzed. This review helped to systematize existing approaches and clarify the key conceptual frameworks.

In the empirical stage, observation, comparison, analysis, and synthesis methods were used. During the data collection process, both qualitative and partial statistical analysis techniques were applied. A systematic approach was also utilized to examine the phenomenon by considering its structural components and interrelationships.

The collected data were carefully interpreted and synthesized to derive meaningful scientific conclusions. To ensure the reliability and validity of the findings, multiple sources were cross-checked and critically evaluated. This methodology provided a solid foundation for achieving the research objectives and addressing the stated research questions effectively.

Results and descussion. The objects of research are bitumens BN60/90, BN40/60 [17,18,19], finely ground rubber powder [20], finely dispersed physically activated natural sands, lime, recycled polyethylene, lignin [21,22,23,24].

The work used standard physical and mechanical research methods, in particular, determination of compressive and shear strength, needle penetration depth - penetration, adhesion strength to concrete, water absorption and other physical and mechanical indicators of composite asphalt concrete materials in accordance with the requirements adopted in the CIS State Standard (State Standard -26589, State Standard -11506, State Standard -11501, 11507 and TU RUZ 14.04.2004).

The results were studied and analyzed. To develop effective compositions of composite asphalt concrete materials using fine rubber powders, their properties were studied.

Table 1 shows the properties of rubber powder by extrusion grinding.

Table 1

Properties of Extrusion Grinded Rubber Powder

Indi cators	Value
Particle size, mm	0,25 – 0,8
Density, kg/m^3	1250 – 1256
Bulk mass, kg/m^3	430 – 435
Compaction coefficient, rel. units	1,28 – 1,29
Angle of repose, degrees.	42 – 43
Specific surface area, cm^2/g	1100 – 2200
pH of aqueous suspension	7 – 8

Oil number, ml/100 g	92 – 105
Dielectric constant, 1 MHz	1,74
Dielectric loss tangent, 1 MHz	0,04
Specific volumetric electrical resistance, Om cm	$1{,}6 \cdot 10^{12}$

As can be seen from the data presented, rubber powder produced by extrusion grinding is qualitatively different in particle structure from powders produced by traditional methods (cutting, roller grinding). The main difference between extrusion-ground rubber powders is a highly developed surface with many irregularities: depressions and protrusions, as well as a high specific surface area. The particles of the dispersed phase have a pronounced asymmetric shape and have a highly developed surface, which determines their tendency to agglomerate.

Analysis of the given data on the geometric parameters of extrusion-ground rubber powder particles in combination with the results of microscopic studies of the particle structure indicates that the shape of TIRP particles is close to ellipsoidal with a semi-axial ratio of 2 – 2.5.

Next, we will consider the influence of organic-mineral ingredients and rubber powders on the physical and mechanical properties of bitumen compositions used to develop elastic-deformation asphalt concrete compositions for producing road surfaces.

Figure 1 shows the dependence of the softening temperature of bitumen on the content of hydrolytic lignin from cotton husks, recycled polyethylene and fine rubber powder.

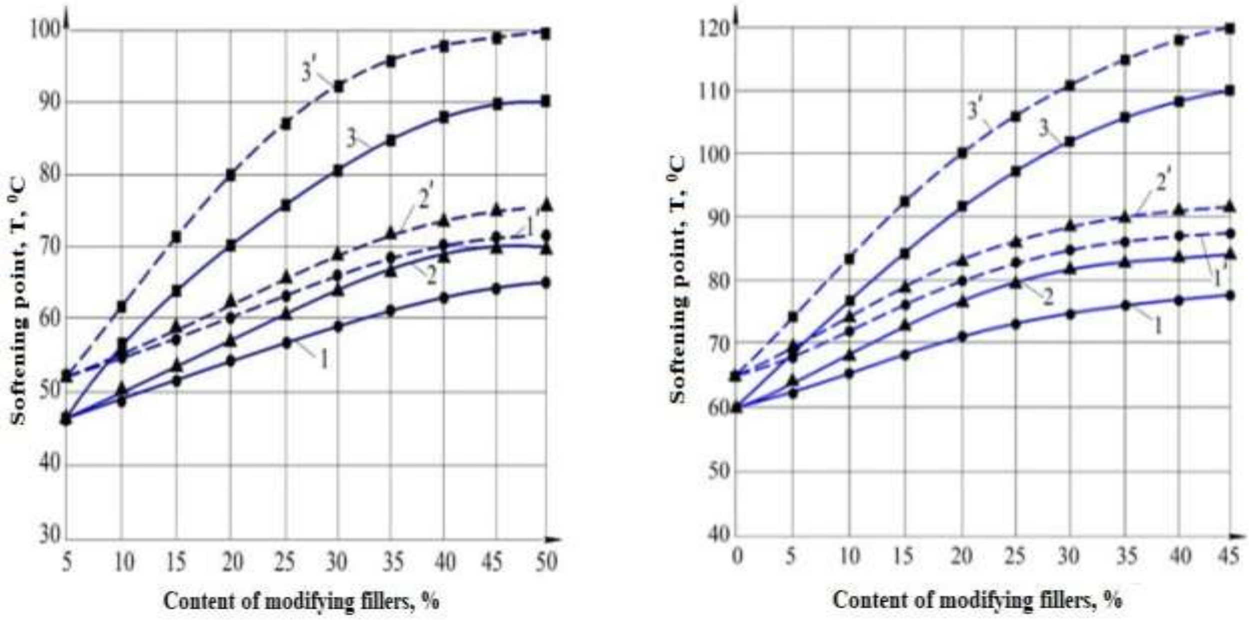


Fig. 1. Dependence of the softening temperature of bitumen grades BND - 60/90 and BND-40/60 not modified with 6% slaked lime (a) and modified with 6% slaked lime (b) on the content of fillers: 1 and 1^1-secondary polyethylene; 2-2^1-hydrolytic lignin from cotton husks; 3-3^1 fine rubber powder obtained by finely grinding waste rubber

As can be seen from the curves in Figure 1, the softening temperature of bitumen tends to increase as the content of hydrolyzed lignin, recycled polyethylene and fine rubber powder increases. Thus, if the softening temperature of bitumen without hydrolytic lignin, recycled polyethylene and fine rubber powder is in the range from 47 to 540C, and with a content of 45-50% hydrolytic lignin, recycled polyethylene and fine rubber powder this figure increases to 65-70, 69-75 and 88-1000C, respectively (Fig. 1a). It can be seen, that the introduction of rubber powder doubles the softening temperature of the composition.

Figure 1.b shows the results of studies depending on the softening temperature of bitumen-rubber compositions based on BND-60/90 and BND-40/60 modified with 6% slaked lime on the content of fillers: 1 and 11-recycled polyethylene; 2-21-hydrolytic lignin from cotton husks; 3-31 fine rubber powder obtained by fine grinding of waste rubber.

As can be seen from the curves in Fig. 1.b it is observed that the softening temperature of bitumen-rubber compositions based on bitumen grades BND-60/90 and BND-40/60 modified with 6% slaked lime increases by 10 and 120C. And with the addition of fine rubber powders to the modified bitumen with slaked lime, it also significantly increases their softening temperature. So, with an increase in the content of fine rubber powder to 50% of the mass of modified bitumen with slaked lime, temperature, the softening of modified bitumen-rubber compositions based on BND-60/90 bitumen increases from 600C to 1100C, and for compositions based on BND-40/60 bitumen increases from 650C to 1200C.

Figures 2 (a, b) show the dependence of the influence of the content of fine rubber powders on the physical and mechanical properties of bitumen-polymer compositions based on BND-60/90 and BND-40/60 bitumens, respectively.

As can be seen from the curves in Figure 2a, the softening temperature of bitumen-polymer compositions based on BND-60/90 bitumens with an increase in the content of fine rubber powders to 50% in the composition increases from 470C to 850C, elongation at 250C increases from 55 cm to 77 cm, strength, adhesion increases from 48 MPa, and penetration decreases from 80 mm-1 to 10 mm-1

Similar results are observed for the bitumen-polymer composition based on bitumen BND-40/60 (Fig. 2b).

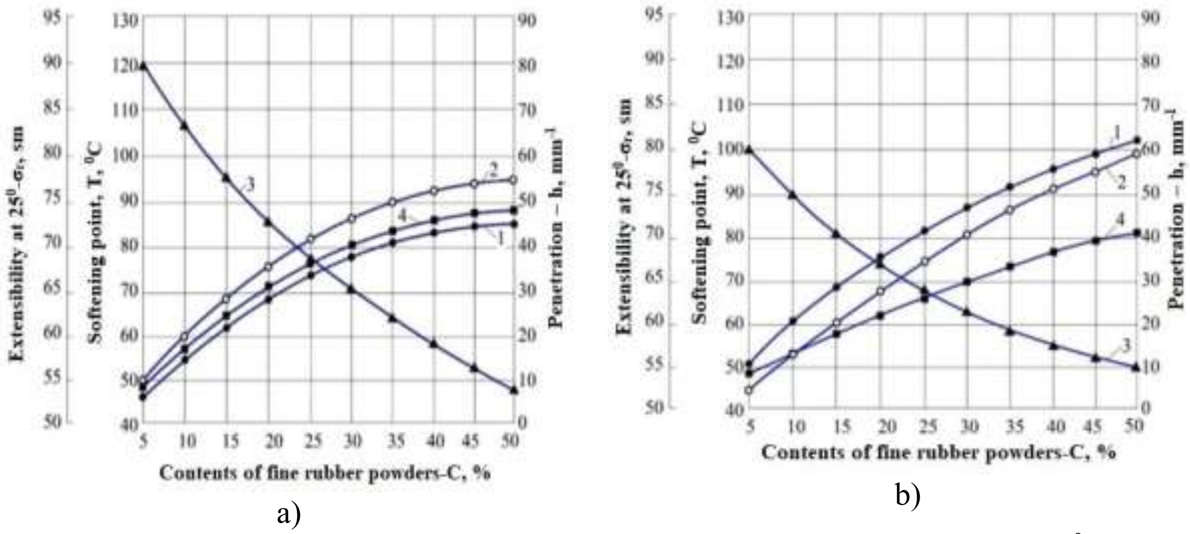
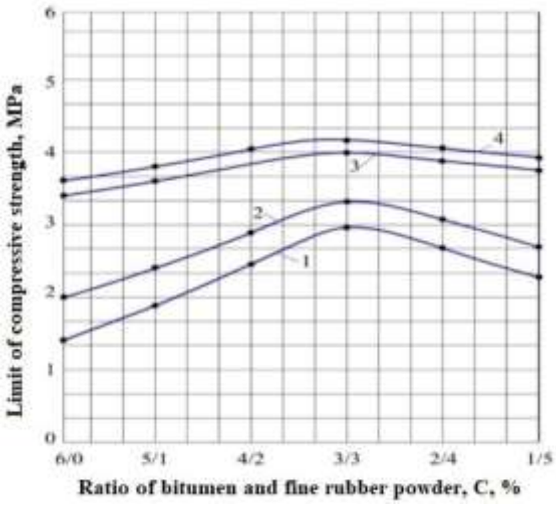
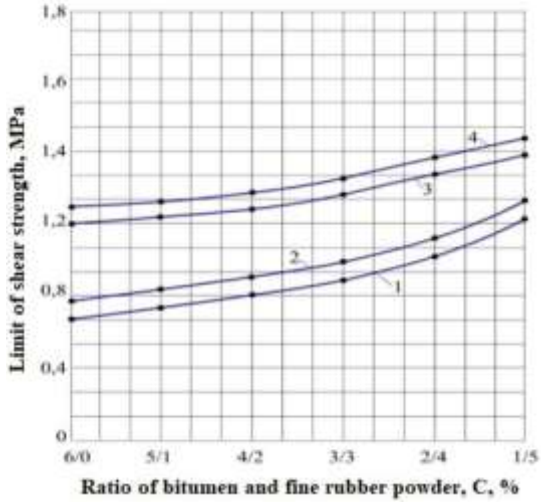


Fig. 2. Dependence of the softening temperature (1), elongation at 25^0C (2), penetration (3) and adhesion strength to concrete (4) of a bitumen-polymer composition based on bitumen grade (a) BN-60/90 and BN-40/60 (b) from the content of fine rubber powders

The results of studies to determine compressive and shear strength are shown in Figure 3.

As can be seen from the course of the curves in Figure 3.a, with an increase in the content of finely ground rubber powders, the compressive strength of asphalt concrete compositions has an extreme character, passing through a maximum, and lies within the range for river sands 4-4.2 MPa, for dune sands 3-3.3 MPa. The maximum compressive strength is observed in a ratio of bitumen and rubber powder of 3/3. Moreover, with an increase in the content of finely ground rubber powders of bitumen-polymer compositions containing the above-mentioned river and velvet sands, the shear strength monotonically increases (Fig. 3 b).





a) b)

Fig. 3. Dependence of the compressive strength (a) and shear strength (b) of composite asphalt concrete materials for road surfaces on the ratio of bitumen and fine rubber powders at a constant content of 1.5% slaked lime, crushed stone 45%, sand 41% and mechanically activated sand 7.5 %

Next Table 2 shows the physical and mechanical properties of the developed elastic-strain composite asphalt concrete materials for producing road surfaces.

Table 2

Comparative comprehensive characteristics of the physical and mechanical properties of the developed elastic-deformation asphalt concrete pavements

Indicators	State Standard 9128-2013	Mix standards for dense hot asphalt concrete			
		Chirchik	Chinaz	Yazyavan	Yangier
Porosity of mineral composition, % volume, for mixtures of types:					
G	22	21	21	18	18
D, no more	22	20	20	19	19
Water saturation, % 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

Residual porosity, % volume	2,2-5,0	3	3,1	3,5	4,0
Ultimate compressive strength, MPa, at temperatures:					
a) +20°C, not less	2,2	4,0	4,2	3,3	3,0
b) +50°C, not less, for mixtures of types:					
G	1,2	1,8	1,71	1,58	1,6
D	1,3	1,9	1,8	1,64	1,61
c) 0°C, no more	12,0	15,0	16,0	14,0	13,0
Water resistance coefficient, not less	0,85	0,90	0,89	0,90	0,88

As can be seen from Tables 2, the developed bitumen-polymer asphalt concrete composition for road pavements fully meets all indicators of physical and mechanical characteristics and even exceeds the requirements of technical specifications TU (Technical conditions) 20-28: 2021 or State Standard 9128-2013.

Conclusion. It has been established that the introduction of fine rubber powders into bitumen-polymer compositions makes it possible to purposefully regulate the structure and increase the elastic-strain characteristics of composite asphalt concrete materials and, accordingly, the resulting road surfaces. A scientifically based approach to the creation of elastic-deformation composite asphalt concrete materials based on local and secondary raw materials using fine rubber powders, gossypol resin and natural sands for the production of asphalt concrete pavements for highways with increased strength and performance properties for use in hot climates and high mountains is proposed. Uzbekistan.

List of used literature

1. N. S. Abed, D. I. Makhkamov, S. S. Negmatov, N. S. Khusanov, B. S. Rakhmonov, and K. M. Inoyatov, *Asphalt Concrete Composite Materials for Road Pavement*. Tashkent, Uzbekistan, 2017, 115 p.
2. S. S. Negmatov, B. B. Sobirov, K. M. Inoyatov, and Y. A. Salimsakov, *Composite Asphalt Concrete Materials for Road Pavement*. Tashkent, Uzbekistan, 2012, 7 p.
3. B. I. Ladygin (Ed.), *Strength and Durability of Asphalt Concrete*. Minsk, 1972, 325 p.
4. G. Suss and U. Karolewski, "Erhöhung der Anfangsgriffigkeit von Asphaltdeckschichten – Ergebnisse einer Pilotstudie," *Asphalt*, no. 4, 1988.
5. Y. Mahmoudov, *Investigation of Strength and Deformation Stability of Asphalt Pavements under High Temperatures in Dry and Hot Climate Conditions*, PhD diss., Moscow, 1973.
6. L. S. Molochnikov, *Physical Chemistry in Road Materials Science*. Ekaterinburg: UGTU Publishing, 2005.
7. I. S. Semirikov, *Physical Chemistry of Construction Materials*. Ekaterinburg: UGTU-UPI Publishing, 2002.
8. I. M. Rudenskaya and A. V. Rudensky, *Rheological Properties of Bitumens*. Moscow: Vysshaya Shkola, 1967.
9. Y. N. Kovalev, "On requirements for rheological models of road asphalt concrete," *Automobile Transport and Roads*, no. 6, pp. 129–134, 1979.
10. G. I. Gorshenina and N. V. Mikhailov, *Polymer Bitumen Insulation Materials*. Moscow: Nedra, 1967.

11. N. F. Pochapsky, “Study of asphalt concrete strength depending on mineral composition,” *Proceedings of KhADI*, no. 26, 1972.
12. I. M. Grushko, I. V. Korolev, and G. M. Borshch, *Road Construction Materials*. Moscow: Transport, 1983.
13. I. M. Grushko and V. M. Sidenko, *Fundamentals of Scientific Research*. Kharkiv: Vyshcha Shkola, 1989.
14. I. M. Grushko and V. A. Zolotarev, *Testing of Road Construction Materials*. Moscow: Transport, 1985.
15. S. S. Negmatov, A. B. Jumabaev, A. A. Ablokulov, and K. M. Inoyatov, “New promising technology of mineral usage in asphalt concrete pavements,” *Composite Materials*, Tashkent, no. 4, pp. 49, 2004.
16. K. F. Shumchik, *Study of Shear Resistance of Sand Asphalt Concrete Pavements in Belarus Conditions*, PhD diss., Minsk, 1999.
17. I. I. Balovneva, *Effect of Grain Composition on Shear Resistance of Asphalt Concrete*, PhD diss., Moscow, 1970.
18. A. S. Kolbanovskaya and V. V. Mikhailov, *Road Bitumens*. Moscow, 1973.
19. *GOST 6617-76: Construction Petroleum Bitumens*.
20. B. B. Sobirov, K. M. Inoyatov, and S. S. Negmatov, “Development of mechanochemical activation technology for road construction materials based on local dune sands and secondary resources,” *Composite Materials*, Tashkent, no. 2, pp. 58–60, 2007.
21. A. L. Markman and V. P. Rzhehin, *Gossypol and Its Derivatives*. Moscow: Food Industry, 1985.
22. S. S. Negmatov et al., “Study of physicochemical characteristics of surfactants based on organo-mineral ingredients from local and secondary raw materials,” in *Republic Scientific-Practical Conference on Actual Problems of Road Construction and Engineering Communications*, Tashkent, 2021, pp. 449–458.
23. S. S. Negmatov et al., “Mechanochemical activation of natural minerals and mixtures as an effective method for improving asphalt concrete properties,” in *Republic Scientific Conference Proceedings*, Tashkent, 2004, pp. 36–38.
24. M. I. Kuchma, *Surfactants in Road Construction*. Moscow: Transport, 1980.