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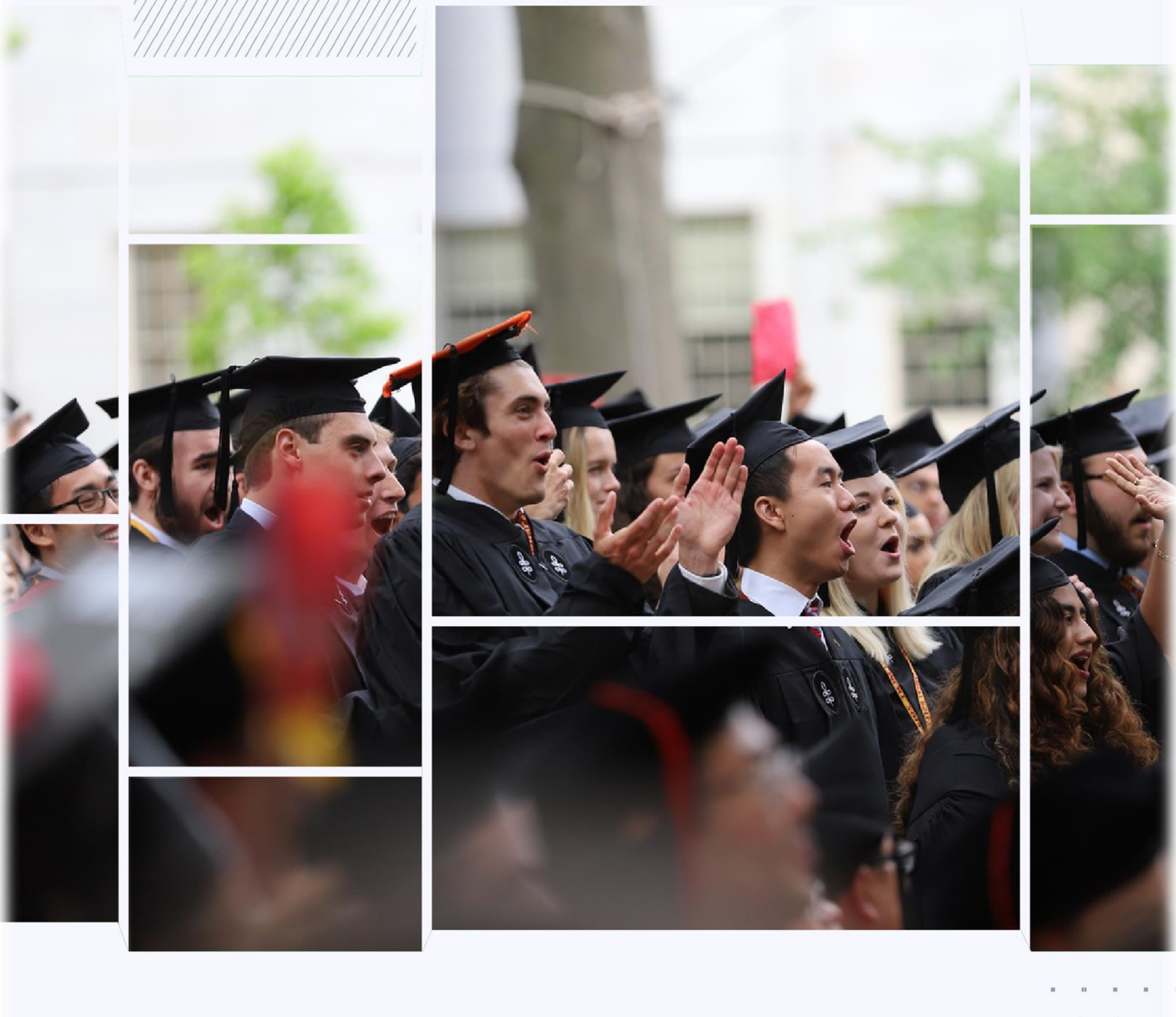

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The method of increasing the performance indicators of the asphalt concrete mixture with the addition of mineral powder obtained from shale rocks, taking into account the operational conditions of the asphalt concrete pavement

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Abstract: In the article, the density of the hot dense asphalt concrete mixture with the addition of activated mineral powder from the Slanesli rock increases, the water absorption index of the asphalt concrete mixture decreases, and the compressive and shear strength increases, the pavement strength increases under operational conditions at high temperatures.

Keywords: Shale mineral powder, mineral powder, granular composition, chemical and particle composition, fine-grained hot dense asphalt concrete, water absorption, water resistance, high temperature compression strength.

In connection with the economic development of the Republic of Uzbekistan, it is known that the existing road networks and their quality do not meet international requirements due to the increase in the speed of transportation of goods on highways. The covering of the main part of existing public highways in the territory of our country is made of fine-grained hot dense asphalt concrete mix. GOST 9128 in this type of fine-grained hot dense asphalt concrete mixes. in the regulatory document, the compressive strength is required to be tested at a maximum temperature of 50°C. In the territory of the Republic of Uzbekistan, the temperature of the air in the summer months is higher than 45-50 ° C, and the temperature of the pavements laid from hot dense asphalt concrete mixture with small grains reaches 65-75 ° C. In this case, wheel marks begin to appear on the pavement, and this, in turn, has a negative effect on the transport performance of the pavement (Fig. 1).

Figure 1: Measurements of wheel track defects on public highways using a 3-meter ruler

The strength of asphalt-concrete mixtures is determined by the ratio of inert material to coarse and fine fillers, and the nature of the binder (bitumen) used. Mineral powders fill the small pores between the coarse and fine aggregates and serve to increase the activity of the binder and thereby improve its binding to the inert material. Mineral powders obtained from limestone material are used as mineral powder in asphalt concrete plants that produce hot dense asphalt concrete mixtures with small grains, which are laid on top of the pavement during the construction and repair of highways in our republic. This type of mineral powder leads to an increase in bitumen consumption in the production of asphalt concrete mixture and a decrease in the strength of hot dense asphalt concrete mixture with small grains at high air temperatures.

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The term mineral aggregate generally refers to mineral fine particles that pass through a standard 200 micron sieve (75 micron). The use and application of mineral mineral powder in hot-dense asphalt concrete mixes is designed to improve the binder properties by reducing the binder. [1]. Mineral powders play a dual role in fine-grained hot dense asphalt concrete mixes, first of all; acts as a part of the mineral inert material by filling the spaces between the large and small fillers in the mixtures, thereby ensuring the strength of asphalt concrete pavements, secondly; when mixed with a binder, mineral powder forms mastic [9].

Filler composition, surface area, and surface absorbency affect the optimum binder composition in a mixture. Current asphalt concrete mix design procedures do not have general limits for the ratio of powder to binder mass. According to the experience of scientists of the Slovak Republic, the optimal ratio of binder to 1 mass unit of powder mass is from 1.5 to 1.75. The high mass of the powder substance in the mixture improves the cohesion and internal stability of the mixture and increases the asphalt elastic modulus, but the mineral powder can increase the hardness of the bitumen, which negatively affects the workability of the mixture. On the other hand, low powder content and high bitumen binder content can increase the susceptibility of the mixture to cracks [10].

The corresponding mineral powder is from natural limestone and dolomite rocks. In addition to the physical and mechanical properties of the mixture, it also has a positive effect on the composite effect between bitumen and inert material. Fillers have different gradation parameters, geometry characteristics, specific surface, surface structure; air voids content and other physico-mechanical properties, it was concluded that the addition of hydrated lime to powders increases the amount of fine particles, specific surface area and Rigden. [10,11]

By the scientists of School of Highway, Chang'an University on August 20, 2019, MDPI Specifications for the construction of asphalt concrete pavements in China [5] In 2004, a part of mineral powder as part of the powder material to improve the adhesion of asphalt concrete to acidic rock and thereby improve moisture stability implies that cement can be used instead. In recent years, it has become common to use cement instead of ore as a filler in asphalt concrete pavements in hot and humid areas. Mixing different powder materials to replace mineral powder to improve the performance of asphalt concrete mixtures is common worldwide.[6-7]

One of the main components of asphalt concrete is mineral powder, which makes up more than 90% of the total surfaces of mineral grains. In addition to [1], mineral powder in asphalt concrete performs two functions, it fills small pores between large and small filler inert materials and improves binding with inert material by increasing the activity of binders, this addition to asphalt concrete increases physical and mechanical indicators.

The starting of mineral powder with the binder is carried out at a temperature of (150 ± 5) ° C, the granularity of mineral powder produced for the production of asphalt concrete mixture, DSTU B V.2.7-121: 2014 (less than 0.071 grains) and 119 mm. 2000 (grains less than 0.08 mm) is evaluated according to the maximum particle size of mineral powders. The mineral powders used in the preparation of fine-grained hot dense asphalt concrete mix meet the requirements of the GOST 16557-2005 document from grinding limestone, shale rock, dolomite, that is, it is probably related to grinding. It is determined that the sample of the mixture will meet the requirements of 2.5% density, at least 35% porosity, and 1.0% moisture content. [8]

Tests of mineral powder obtained from shale rocks in Samarkand region of the Republic of Uzbekistan were conducted in laboratory conditions, according to GOST 16557-2005 was

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compared with the requirements of the regulatory document. According to the test results, mineral powders obtained from shale rock have a natural moisture content of 0.8%, density of 2.6 g/cm3, porosity of 28.9%, the density of the sample mixed with mineral powder and bitumen is 1.6%, and the product obtained from shale rock is MP-1 brand. mineral powder meets the requirements of the regulatory document GOST16557-2005 [2,3]

The mineral powder obtained from shale rocks is an activated mineral powder of type MP-1, the mineral powder obtained from shale rocks increases the binder activity in the asphalt concrete mixture. On the territory of our republic, shale rocks can be found in the area of Karasoy village, Sh.Rashidov district, Samarkand region and Jizzakh region. Shale mineral powder is obtained by crushing and pulverizing these shale rocks. The mineral powder obtained from shale rocks that meets the requirements of Table 1 of the GOST 16557-2005 regulatory document in terms of granularity fills the small pores between the large-grained aggregate stone material and the fine-grained aggregate sand in the fine-grained hot asphalt concrete mixture and increases the average density of the mixture. Mineral powder obtained from shale rocks has a high surface bonding with bitumen, so the binder in the composition improves the bonding of the mineral part with bitumen. [2.3.4]

The average density of the mixture was calculated using the following formula: [13].

$$\rho_m = \frac{g\rho^{в}}{g_2 - g_1} \qquad (1)$$

g – the weight of the sample in air, г;
$\rho^{в}$ – density of water, g/cm ^{3};
g_1 – weight of the sample in water after the sample is in water for 30 minutes, g;
g_2 – weight of the sample in air after the sample is in water for 30 minutes, g;
The water absorption of the mixture was calculated using the following formula

$$W = \frac{g_5 - g}{g_2 - g_1} 100 \qquad (2)$$

g – weight of the sample in air, g;
g_1 – weight of the sample in water after standing in water for 30 minutes, g;
g_2 – weight of the sample in air after standing in water for 30 minutes, g;
g_5 – sample weight in air after storage in vacuum equipment, g;

Chemical composition of shale: The composition of oxides in the most common oil shale - SiO^2 47,4%, Al^2O^3 8,7%, Fe^2O^3 10,1%, CaO 9,8%, MgO 24,1% [2,3]

Slate is a natural and environmentally friendly material, characterized by good soundproofing, high durability and frost resistance, which makes it resistant to extreme temperature effects. This natural stone is resistant to corrosion processes and ultraviolet rays, and these properties do not decrease during the entire service life.

The physical properties of shales in different regions are as follows:
The average density is 2.71 g/cm3
Water absorption - 0.97%,
Bending strength limit - 87.6 MPa;
Frost resistance - 100 cycles.
Tensile strength - 1.80 g. cm2
Hardness on the Mohs scale is from 3 to 6

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Chemical composition of mineral powder from shale rock

Table 1

Index	Quantity (%)	Naming	Chemical formula
A	56,7	Silicon dioxide	O^2Si
B	36,2	Aluminum oxide	Al^2O^3
C	6,0	Titanium dioxide	O^2Ti
D	0,8	Lime	CaO
E	0,4	Iron oxide	Fe^2O^3
	38,7	Undefined part	

Tests of mineral powder obtained from shale rocks in Samarkand region of the Republic of Uzbekistan were conducted in laboratory conditions, according to GOST 16557-2005 was compared with the requirements of the regulatory document. The test results are shown in Table 2 below.

table 2

№	Index names	Unit of measure	The value of indicators		
			Standard price	Average value obtained	Regulatory compliance
1	Natural humidity	%	0-1,0	0,8	-
2	Grain composition, mm	1,25	At least 100	99,6	Fits
		0,315	At least 90	91,7	Fits
		0,071	At least 80	81,2	Fits
3	Density	$г/см^3$	not moderated	2,6	-
4	Porosity, at least	%	30	28,9	Fits
5	Proliferation of a sample of bitumen mixture with mineral powder		1,8	1,6	Fits

The quality and durability of asphalt-concrete mixes are greatly influenced by the degree of fineness of mineral powders and the shape of their particles. Therefore, microscopic analysis of mineral powders obtained from shale rocks, mineral powders obtained from limestone material and mineral powders obtained from azzicrete material was obtained.

Particle appearance of mineral powder obtained from shale rocks in optical microscope Motic VA 210

Figure 1.

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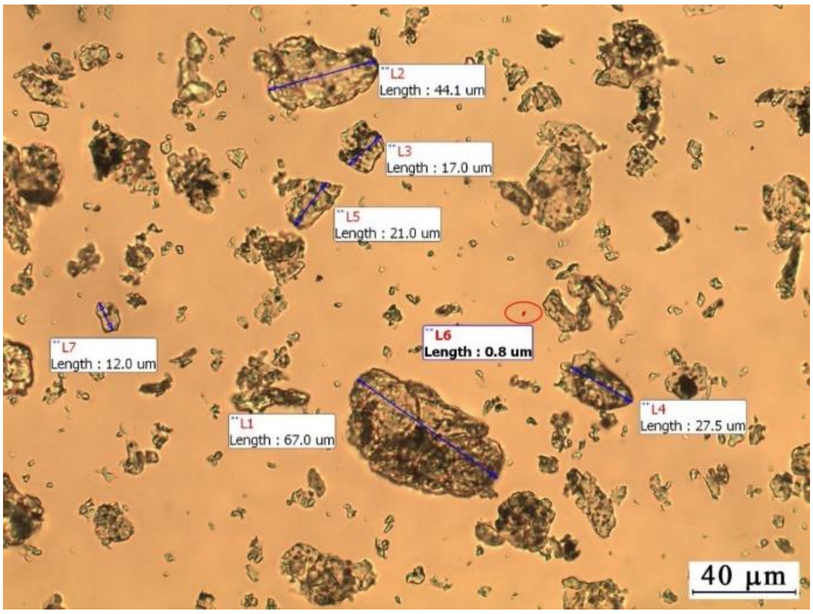

Mineral powder obtained from shale rocks was found to be composed of particles of the following sizes by optical microscopic analysis:

L1- 67 microns - 0.9%;
L2- 44.1 microns - 1.78%;
L3- 17.0 microns - 5.35%;
L4 – 27.5 microns - 3.57%;
L5 – 21.0 microns - 6.25%;
L6- 5.0 to 0.8 microns- 71.42%;
L7- 12.0 microns - 10.73%.

96.35% of this mineral powder is made up of cubic particles and 3.65% of needle-shaped and leaf-shaped particles.

It was found that the mineral powder obtained from limestone consists of particles of the following sizes: L1- 70 microns - 0.4%;

L3- 30.0 microns - 1.6%;
L5, L7 – 21.0 microns - 2.39%;
L6 – 22.4 microns - 2.39%;
L8- 34.5 microns - 1.19%;
L9- from 9 to 20, micron - 11.16%;
L10- from 0.8 to 9, micron - 79.68%;

6.72% of this mineral powder consists of needle-shaped and leaf-shaped particles. Needles are mainly found in particles with a size of 30-70 microns.

Optical microscope view of particles of mineral powder obtained from limestone material on Motic VA 210.

Figure 2.

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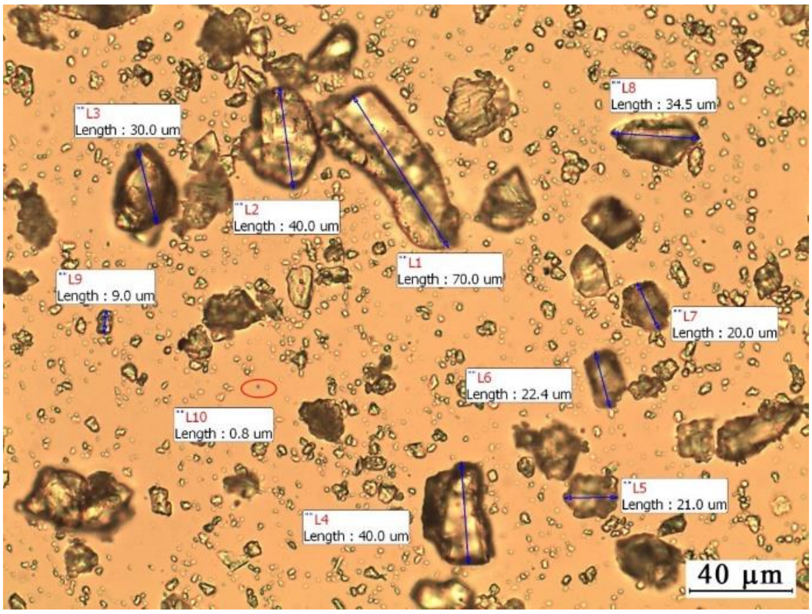
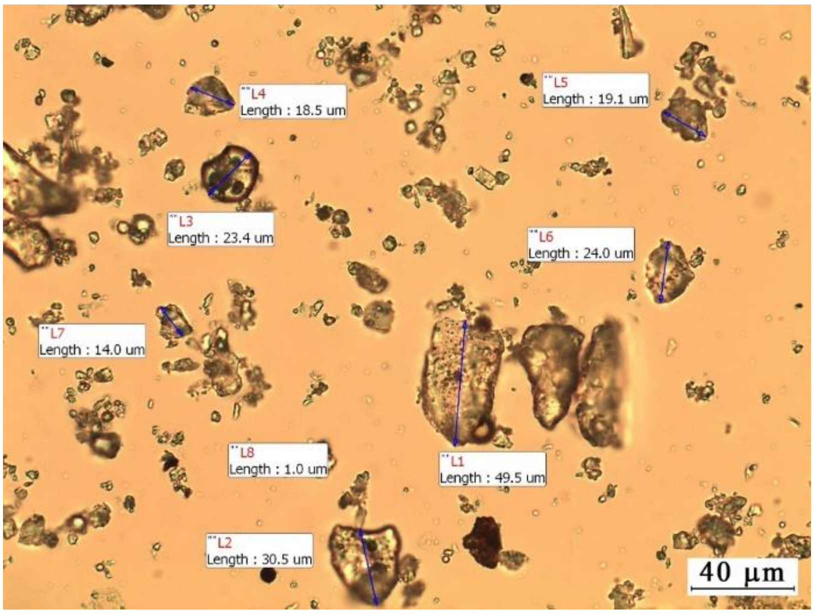


The appearance of particles of mineral powder obtained from azicrete material in an optical microscope Motic VA 210

Figure 3.



L1- 49.5 microns – 3.27%;
L2, - 30.5 microns - 1.63%;
L3, L6- from 23.4 to 24.0 microns - 3.27%;
L4, L5 – from 18.5 to 19.1 microns - 3.27%;
L7 – from 14.0 to 18.5 microns - 6.60%;
L8- from 1.0 to 14.0 microns - 81.96%;

7.12% of this mineral powder consists of needle-shaped and leaf-shaped particles. Needles are mainly found in particles larger than 45 microns and in the size range of 1-14 microns.

Based on the results of the above optical analysis, the following conclusion was reached when comparing 3 types of mineral powders to each other:

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The particle sizes of the mineral powder obtained from the shale rock are arranged in a close sequence. The advantage of this is that it makes it possible to almost completely occupy the part that needs to be filled between the large and small aggregates in the mixture. [2,4]

Mineral powder particles obtained from shale rock were distinguished by their cubic shape and the presence of very small amount of needle-like particles. Based on the world experience and previous scientific works, the amount of cubic particles in the mineral powder affects the binding of the asphalt concrete mixture with the inert stone material and serves to increase the strength as a result.

Chemical composition of mineral powder obtained from shale rock

Table-3.

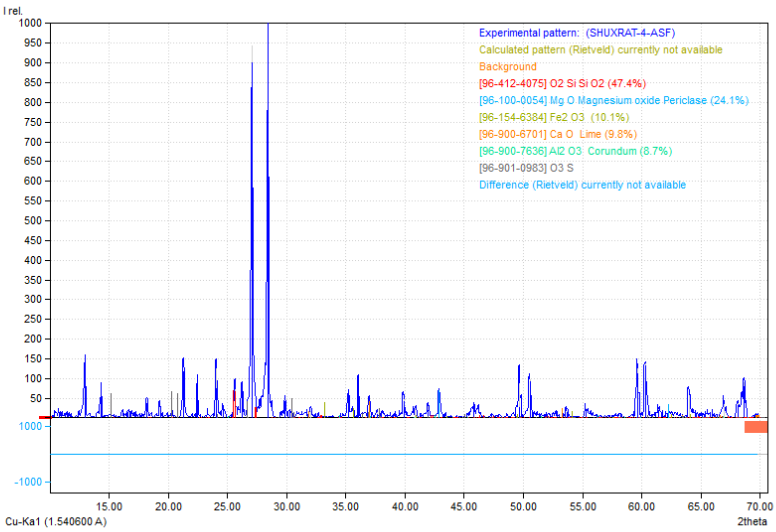
Index	**Amount (%)**	**Name**	**Formula sum**
A	47.4	Si O2	O^2 Si
B	24.1	Magnesium oxide Periclase	Mg O
C	10.1		Fe^2 O^3
D	9.8	Lime	Ca O
E	8.7	Corundum	Al^2 O^3
	93.2	Unidentified peak area	

Degree of crystallinity analysis

Profile area	Counts	Amount
Total area 48	465294	100.00%
Diffraction peaks	89388	19.21%
Background	375906	80.79%
Instrumental background	0	0.00%
Amorphous phases	375906	80.79%

Degree of crystallinity (DOC) = 19.21%
Amorphous content (weight %) =80.79%

Figure 4



Mineral powder substances play an important role in increasing the workability and stability of asphalt concrete mixtures. Different types of mineral powders have different effects on the performance of asphalt concrete mixtures. Mineral powders used in the preparation of asphalt concrete mixtures are obtained by grinding limestone, dolomite and other carbonate rocks and turning them into powder. A lot of research has been done to study the main properties of mineral

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powder and its quality, and the technology of its production is similar to the technology of grinding natural and artificial stone materials. These materials are widely used in manufacturing industries such as cement, ceramics and refractories.

Mineral powder obtained from shale rock increases the activity of binding bitumen in the composition of fine-grained hot dense asphalt concrete mixture, forming an asphaltene substance and improving its binding with coarse and fine aggregates. As a result, the physico-mechanical indicators and density of fine-grained hot dense asphalt concrete mixtures increase, and the coating increases water absorption, compression resistance, sliding resistance, and water resistance. Asphalt-concrete mixtures with mineral powder obtained from shale rocks prevent the occurrence of defects such as longitudinal undulating and concentric wheel track deformations, sliding, deformation, grooves in the pavement caused by traffic.

Currently, the pavements laid on public highways of the Republic of Uzbekistan are damaged due to the release of binding bitumen on the surface of the pavement, the appearance of wheel marks, and the high temperature in the summer months in our country. Currently, the majority of public highways are covered with one type of pavement, the use of small-grained hot dense asphalt concrete mixtures in repair works, the quality of mineral powders in asphalt concrete mixtures do not meet the requirements of the regulatory document, and even in cases where they are suitable, they do not affect the strength of the mixture.

Scientific and research work on increasing the strength of fine-grained hot dense asphalt concrete mixes with mineral powder from shale rocks, test-measurement work in laboratory conditions according to GOST 12801-98 standard document, test works were carried out and GOST 9128-2013 "Smesi asfaltobetonnye, polimerasfaltobetonnye, asphalt concrete, polymer asphalt concrete for automobile roads and airfields" T.U. compared according to the requirements of the regulatory document.

Test results of physical and mechanical properties of asphalt concrete mixture in laboratory conditions:

Table 4.

Amount of binder, %	Average density, g/cm^3	Water absorption, %	Water resistance, %	Compressive strength at 20°C, MPa	Compressive strength at 50°, MPa	Compressive strength at 60°C, MPa	Compressive strength at 700 C, MPa	Compressive strength, MPa
4,4	2,35	4,53	0,81	4,80	1,63	1,49	1,34	0,7
4,5	2,39	3,15	0,77	3,09	1,05	0,96	0,86	0,86
4,6	2,35	3,63	0,90	4,15	1,41	1,29	1,16	0,71
4,8	2,35	3,41	0,79	3,64	1,24	1,13	1,02	0,75
5,0	2,38	3,11	0,75	3,56	1,21	1,10	1,00	0,82

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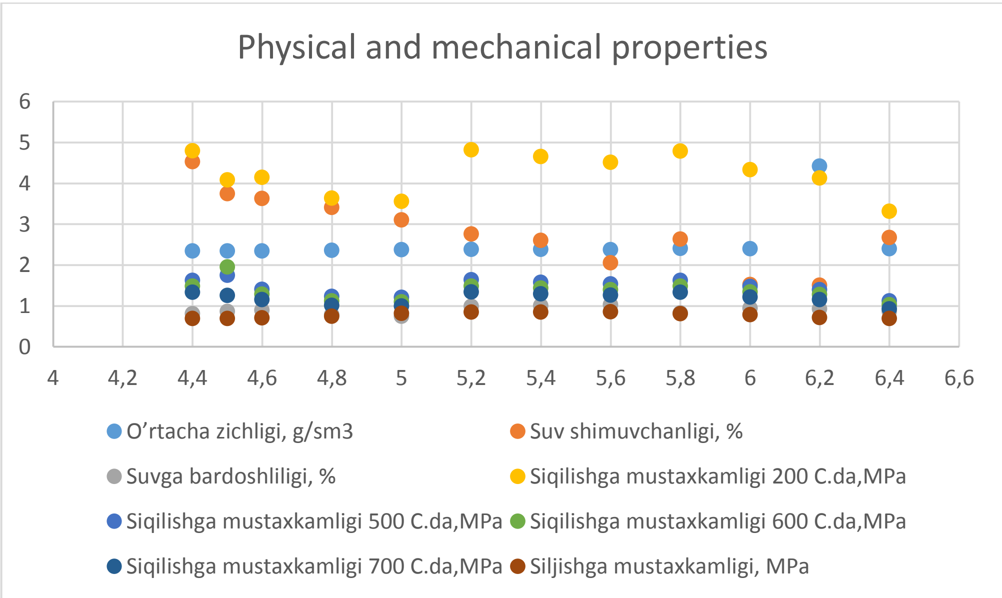
5,2	2,39	2,76	0,99	4,82	1,64	1,49	1,35	0,85
5,4	2,39	2,61	1,01	4,66	1,58	1,44	1,30	0,85
5,6	2,38	2,06	1,03	4,52	1,54	1,40	1,27	0,86
5,8	2,41	2,64	0,83	4,79	1,63	1,49	1,34	0,81
6,0	2,40	1,53	0,95	4,34	1,48	1,35	1,22	0,79
6,2	4,42	1,51	0,93	4,13	1,40	1,28	1,16	0,72
6,4	2,40	2,68	0,87	3,32	1,13	1,03	0,93	0,70

Graph of comparison of physical and mechanical properties of asphalt-concrete mixture in laboratory conditions.

Figure 5



The viscosity index describes the visco-plastic properties of asphalt concrete. Therefore, the deformation resistance of asphalt concrete in the summer season and its deformation at low temperatures can be evaluated by balancing its viscosity using a constant physical indicator.

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The viscosity of the intact structure of asphalt concrete mixtures was studied by breaking cylindrical samples. The study of changes in the viscosity of asphalt concrete was carried out at different deformation rates (1, 3, 5 and 10 mm / min) and at different sample temperatures (0 ° C, 20 ° C, 50 ° C). The equilibrium viscosity was determined by the formula [12].

$$\eta = \frac{R h_0^2 (h_0 - h_1) x^2}{(d_{max} - d_{min})} * 10^6 \qquad (3)$$

R- compressive strength, MPa;
h0 is the height of the sample before the test, cm;
h1 - height of the sample after the test, cm;
Dmax is the maximum diameter of the image at 1/2 height after the test, cm;
Dmin is the minimum diameter of the sample, cm;
V is the stroke speed of the press piston, cm/sec.

Table 5

Test indicator	**Unit of measure**	**Binder content 5.2%, mineral powder 5.0%**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
R	МПа	4,8	4,8	4,7	4,7	4,7	3,8	3,5	3,6
h_0	мм	7,0	7,2	7,2	7,1	7,2	7,0	7,1	7,1
h_1	см	6,3	6,1	4,8	5,4	5,0	6,4	5,2	6,0
D_{max}	см	7,3	7,8	7,7	7,9	7,8	7,6	7,9	7,7
D_{min}	см	7,1	7,1	7,1	7,1	7,1	7,1	7,1	7,1
V	см/сек	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0
R*H1 (a)		33,32	34,70	33,84	33,65	33,77	26,81	24,92	25,42
H1-H2 (b)		0,70	1,10	2,40	1,70	2,20	0,60	1,90	1,10
a*b*2		46,65	76,35	162,43	114,42	148,58	32,17	94,70	55,92
Dmax-Dmin		2,88	10,43	8,88	12,00	10,43	7,35	12,00	8,88
N=		16,20	2,48	11,84	5,09	1,48	2,48	3,48	4,48
		16197222,2	2483108,1	11836643,4	5089143,8	1481879,2	2481879,2	3481879,2	4481879,2

Conclusion: The fine-grained hot dense asphalt concrete mixture with mineral powder obtained from shale rocks with a binder content of 5.2% leads to an increase in the service life of the pavement when the air temperature is high for the climatic conditions of our country. To come to this conclusion is the comparison of the physical and mechanical properties obtained by the amount of the binder above. The mineral powder obtained from shale rocks increases the activity of binding bitumen in the asphalt concrete mixture and occupies inert materials forming an asphaltene substance on the surface. The density of the asphalt-concrete mixture increases and the water permeability decreases, as a result of which the pavement compressive strength, water resistance,

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and sliding resistance increase. The use of binder bitumen compared to the inert material in the pavement laid from fine-grained hot dense asphalt concrete mixture leads to increased strength at high air temperatures and does not cause longitudinal wheel marks and sliding defects.

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