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Research of Shungit Mineral Powder Effect on Stone – Mastic Asphalt Concrete Deformation Stability in Operating Conditions

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Abstract

Topicality of shungit application as mineral powder is substantiated in the paper. Information on preparation of crushed stone – mastic based on shungit mineral powder and construction of experimental surface with its application is described in the article. It also contains information about physical- mechanical properties of kerns from surface on experimental and control sections. There was given an assumption about possibility of producing bituminous concrete pavement with higher deformation property.

Keywords: shungit, dispersed reinforcing, fullerenes, graphenes, crushed stone mastic composite, mineral powder, shungit containing composites, segregation.

INTRODUCTION

Practically all shungit containing mineral fields have been explored and mined on Karelian Isthmus of Russian Federation., Three deposits with counted up shungit reserves have the status of field. They are Maksovskoe - 30mln tone, Zazhogino – 4,0mln tone, Kaleinoe – 20mln tone. Shunga field with reservation of 2mln tone is in protection zone and cannot be mined. Shungit containing rock was also found in different places near Lake Onega. The most suitable term represents the nature of shungit substance main part is the term "antroxolite coal" suggested by N.A. Orlov in 1932.

There is also known small shungit reservations in Mexico and Kazakhstan. Shungit containing rock is applied in different industry brunches in Russian Federation. In the USSR on the base of Nigozyorsk field there was existed the production of shungisite for the needs of construction industry. Shungit containing rock activity depends on different carbon forms content which exceeds 50% in Karelia field.

It is known that shungit can be applied for protection from both heavy metals and their compounds, and electromagnetic and ionizing radiation. Over the last 20 years the scientists from many countries become more active in their researches on studying shungit properties and its different purposes of application. The number of scientific publications is great but for fullerenes and graphenes discovery former Russian and now American and English scientists received two Nobel prizes. There was even proposed that the third stage of civilization development can be connected with shungit. [1;4]. During the last 5 years the scientists from Voronezh State University of Architecture and Civil Engineering together with the scientists from MADI (GTU) and BGTU by the name of Shuhov have been carrying out the laboratory and experimental researches on argumentation the possibility to apply shungit as mineral powder in different road concrete mixes. In Voronezh GASU there were researches in the frame of the contract with public corporation 'Teva-shungit", research institution "Development of technology on application of fine dispersed mineral powder from

carbonaceous rock for construction of deformation resistant road surface from asphalt concrete. Preliminary results received in Voronezh GASU allow expressing opinion about the possibility to create deformation resistant bitumen-shungit composites for road surface construction with high freight traffic density. .

One of the most important traffic – operational performance during the whole period of vehicle life cycle is road construction durability. The ability to resist the drift process development and destruction under the effect of circumferential and normal tension appeared in constructive layers and subbase caused by specified load on road surface is realized as road pavement. Road pavement structure can considered durable when evenness performances certify the requirements and when there are no fractions in bituminous concrete pavement. Without fine dispersed mineral powder mineral powder with more than 60% content of particles smaller than 0,071 мм and activated mineral powder with more than 80% content of such particles can be considered the main asphalt concrete structure forming component. Nowadays it is not possible to provide road pavement durability without such a powder. That is why the lack of mineral powder, which is needed for many road construction organizations, stimulates the research of new non-traditional materials and technologies for producing mineral powder which can substitute traditional one keeping and improving running abilities of asphalt concrete. There is suggested to solve the problem of increasing the road blanket deformation and corrosion rigidity by organization the production of mineral powder from shungit rock and its application in mineral mixes. Introduction of dispersed reinforcement with the help of different fibroelements in the road construction allow creating pavement with high operating properties. Application of shungit mineral powder with its unique properties allows providing road pavement overhaul periods increase [2].

PROCESSING TECHNOLOGY

Experimental improvement of theoretical propositions is carried out in the road laboratory of Voronezh GASU but physical-mechanical properties are investigated under real operation conditions while observing the state of pavement from crushed stone –mastic asphalt-concrete based on shungit mineral powder in Orehovo-Zuevo district of Moscow region built in 2011. During the period from 5th up to 31 of August, 2011 according to the Russian road agency innovation work there were carried out research –production works on application of shungit mineral powder in crushed stone asphalt concrete mix.

Crushed stone of 40-70 size fractions was delivered by motor transport from the open pit “Kondopozhsky” of Karelia republic. After the experimental grinding there were determined preparing mineral powder operating practices. Shungit powder was produced in Naginsky road building factory with shipping directly into cement truck and further delivery into Orehovo-Zuev asphalt factory. Pneumatic transport was used for in-plant transportation of mineral powder from shungit.

Testing of shungit mineral powder and other components of crushed stone mastic mix (gabbro-diabase crushed stone of 15-20mm size fraction, crushed stone of 10-15 мм size fraction, crushed stone of 5-10 mm of size fraction, crushed sand from gabbro-diabase, limestone mineral powder and bitumen of BND 60/90 grade), adhesive admixture “Viatop” was carried out in Voronezhsky GASU, MADI and in laboratories of asphalt-concrete factory (fig.1)

Size composition of asphalt concrete mineral proportion is shown on fig. 2 and in tables 1-5.

Figure 1. Adhesive admixture “Viatop” in Road Repair and Construction Executive of Oreho-Zuev district in Moscow region.

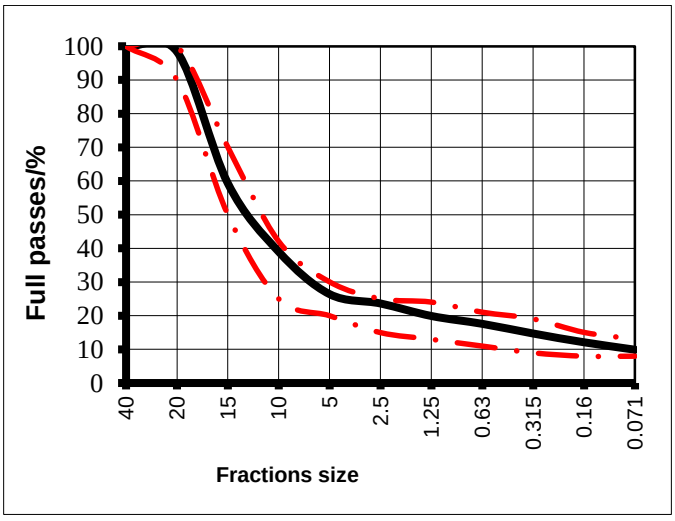

Figure 2. Grain content of asphalt concrete mineral proportion. The amount of bitumen should be corrected during the operating process with account of physical-mechanical properties of compacted asphalt-concrete.

Table 1: Grain proportion of crushed stone №1 from gabbro-diabase

Oversize product % mass.	Fraction size, мм								Crush ability in cylinder, % mass.	Frag.form
	40	20	15	10	5	2,5	1,25	< 1,25		
Partial	0,00	2,67	65,13	31,73	0,37	0,10	0,00	0,00	7,71	Cubiform
absolute	0,00	2,67	67,80	99,53	99,90	100,00	100,00	100,00		

Table 2: Grain proportion of crushed stone №2 from gabbro-diabase

Oversize product % mass.	Fraction size, мм											Crush ability in cylinder, % mass	Frag .form
	40	20	15	10	5,0	2,50	1,25	0,63	0,315	0,14	< 0,14		
Partial	0	0	0,20	9,80	89,30	0,70	0	0	0	0	0	10,4	Cubiform
absolute	0	0	0,20	10,00	99,30	100,00	100,00	100,00	100,00	100,00	100,00		

Crushed stone №1 и №2 from gabbro-diabase according to grain proportion, strength, slime, clay content meet the requirements of State Standard 8267-93 and 3344-83.

Table 3: Sand from gabbro-diabase crushing siftings (fr. 0-5)

Oversize product % mass.	Fraction size, мм										Fineness modulus	Fragform
	15	10	5,0	2,50	1,25	0,63	0,315	0,16	0,071	< 0,071		
Partial	0	0,00	5,40	18,70	25,90	15,30	13,80	10,90	5,80	4,20	2,82	Cubiform
Absolute	0	0,00	5,40	24,10	50,00	65,30	79,10	90,00	95,80	100,00		

Table 4: Mineral powder. Main characteristics

Field	Polotnyanozavodsk administration career management
Plant of production	Polotnyansky
Type	nonactivated
Fraction form	ball

Oversize product % mass.	Fraction size, mm							
	5,0	2,50	1,25	0,63	0,315	0,16	0,071	< 0,071
Partial Absolute	0	0	0,7	1,4	7,3	8,3	10,7	71,6
	0	0	0,7	2,1	9,4	17,7	28,4	100

Grade of crushing of row rock, MPa	100
Density , gr/cm^3	2,69
Propotion of fraction smaller 1.25 mm, % масс.	99,3
Propotion of fraction smaller 0.071mm, % масс.	71,6
Bitumen proportion (Sfzfsšen) bitumoemkost	61

Table 5: Bitumen

Plant of production	Ryazan plant
Brand	BND 60/90
Penetration at 25^0 C, 0,1 mm	73
The same at $0\ ^0$C, 0,1 mm	21
Softening temperature, ^{0}C	48
Fragility temperature, ^{0}C	-16
Tensility, cm	57
Adhesion	cured

After the correction of mix compound the scientists of Voronezh GASU developed " The prepositions on mineral powder from shungit application while producing crushed stone asphalt concrete mix ".

Crushed stone mastic mix was prepared in asphalt-concrete factory on asphalt mixing plant «Bernardi» with productivity of 100 т/ч (fig.3)

At visual estimation of crushed stone mix it is appeared to be homogeneous , in three probes of the same mixing there were no clots, agglomeration of bitumen, mineral powder, mineral material grain not covered with bitumen; unmixing was not observed.

Figure 3. Control for the process of mix compound batching in the control point of Orehovo- Zuevo factory.

According to the normative document requirements homogeneity on average density should be determined at mix preparation technology in asphalt concrete factory. While estimating the homogeneity on average density values at asphalt concrete factory 3-4 samples from the same batch were taken.

The differences in samples average density performances were less than 0,03gr/cm^3, that is the mix was homogeneous.

At heterogeneity of shungit containing mix it is necessary to determine the proportion of initial components, the temperature of stone material at its discharge from the dryer drum and the temperature of ready mix and also the time of dry mixing.

The surface upper layer was constructed in September, 2011 on the road section km 0+000 – km 5+000 Egorjevsk-Ryazan highway of Bolshoi Moscow Koltso (left line). Crushed stone mastic mixture on lime mineral powder was placed on the sections km 3+000 – km 3+723 and 4+250 – km 5+000 (control section). Pilot surface from crushed stone mastic mixture with shungit mineral powder was constructed on km 3+723 – km 4+250.

Asphalt concrete mixture of grade 20 was transported by lorries Kamaz and Maz for 52km distance.

Mix was placed on the lane of 3,75m width by asphalt spreading machine "Fogel" without traffic flow stopping. As soon as the placing was done without reloader there were important the followings:

- to determine correctly the time of unloading, e.g. to be sure that there is needed amount of mixture in receiving hopper feeder and in screw conveyer chamber;
- not to admit the dynamic contact with asphalt spreading machine, as in this case the layer shifting and deformation on surface caused by asphalt spreading machine finishing plate is possible. A driver should stop the vehicle before asphalt spreading machine pushing rollers to determine the moment when the travelling rollers start to move a disinhibited car.
- to open the back side lock in time.

Use the rollers of brand «Hamm» of 8 и 10 tone mass for consolidation. The specificity of crushed stone mastic asphalt concrete consolidation is:

- consolidation of crushed stone mastic layer is done with heavy plain roller of static action of 8-10kg mass, rigid rollers were treated during rolling;
- as-cast layer of crushed stone mastic was consolidated with rollers which move for short stints at a speed of 5 – 6km/h in direct nearness to asphalt spreading machine at maximal temperature .
- consolidation of crushed stone mastic layer was finished after 4-6 passes along the same track by a roller of static action with 8-10 tone mass;
- an effective roller action was determined during the test laying and consolidation of mixture in dependence on air temperature;
- crushed stone mastic surface is to consolidate at not below 80°C.

Laying and consolidation process was accompanied with temperature control of mixture inside the vehicle and during all technological operations.

The research results done by Chernousov D.I. [3] show that the temperature of shungit containing crushed stone mastic mix during road pavement structural layers construction should correspond with the temperature given in table 6

Table 6: Recommended crushes stone mastic mix in dependent on bitumen grade

bitumen grade	Bitumen oil road 60/90	Bitumen oil road 90/130	Bitumen oil road 130/200
Mix temperature not less	145	140	135

At laying of mixtures based on shungit mineral powder the special attention was paid to lines conjugation:

- perpendicularity to road axis is provided by the cross conjugation;
- edges of laid line were cut vertically and lubricated with bitumen emulsion;
- cold cross junction was heated, and together with this layer slab vibrator was placed over the before laid pavement edge, after that conveyer screw chamber was filled with hot mix.

The observation over the pavement state and physical-mechanical asphalt concrete properties is in the sphere of the research program on pilot section. That is why in August, 2011, in January, 2012 and in July 2013, the kerns were sampled from the pavement (fig.4-5, Table7).

Figure 4. Sampling of asphalt concrete pavement on pilot site

Table 7: Journal of control kerns sampling on Egorjevsk-Ryasan highway pilot plot on Moscow Ring

Point number	Material of pavement upper layer	Place		To the left from the road axis, m	kern number
		km	+		
1	stone crushed mastic mixture – 20 with shungit mineral powder.	4	071	1,60	1/1
				1,30	1/2
				1,00	1/3
2		4	000	1,60	2/1
				1,30	2/2
				1,00	2/3
3		3	865	1,75	3/1
				1,55	3/2
				1,40	3/3
5	stone crushed mastic mixture -20 with limestone mineral powder	3	688	1,80	5/1
				1,50	5/2
				1,20	5/3
6		3	552	1,70	6/1
				1,50	6/2
				1,30	6/3

Research results of physical – mechanical samples of asphalt-concrete from pilot and control sites are given in table8.

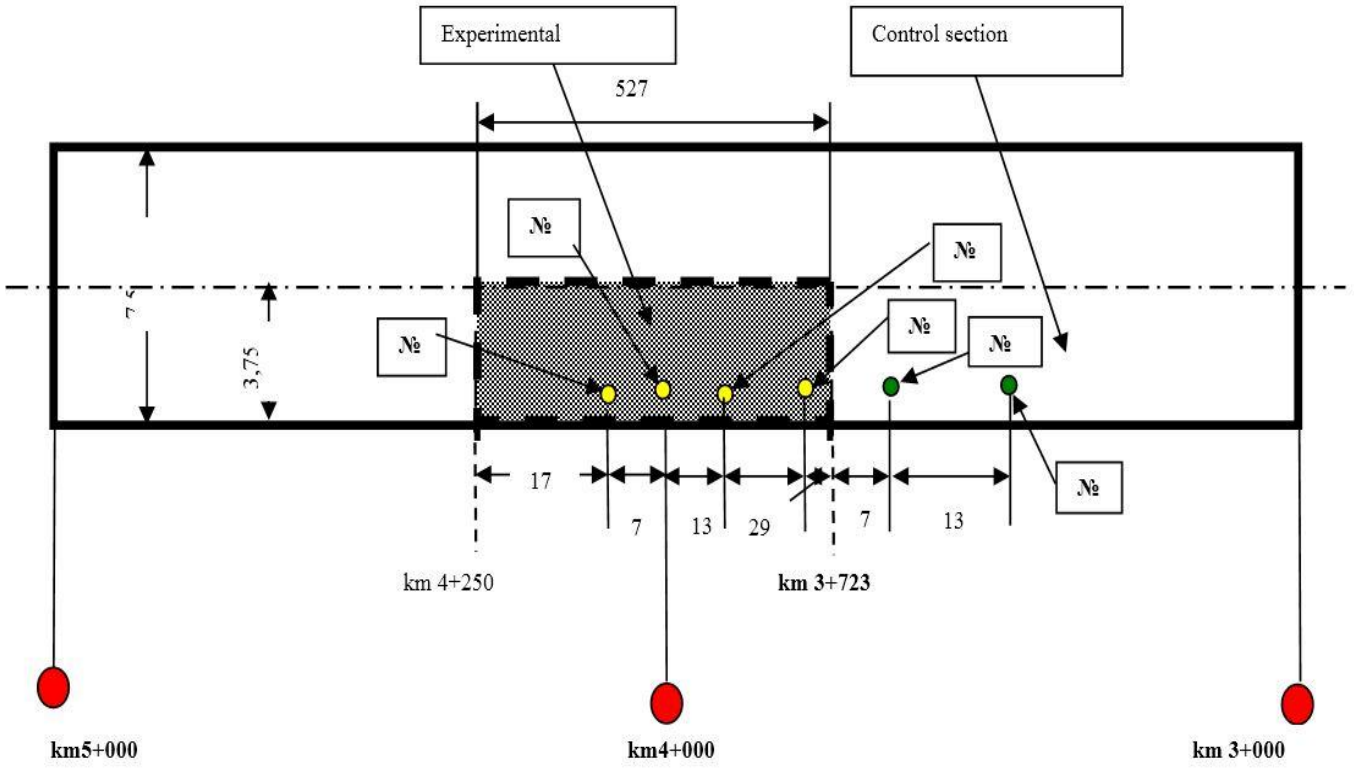

Figure 5. Diagram of control kerns on pilot site on Bolshoi Moscow Koltzo on Egorjevsk-Raysan highway

Table 8: Physical-mechanical properties of asphalt concrete samples on pilot and control

Sections

Sampling date	Number of kern sample	Place of sampling	Thickness of layer (upper, lower)	Pavement samples							
			Fact	Weight of dry sample on air, g	Weight of dry sample on air after 30 min keeping in water, g	Weight of sample in ater after 30 min keeping in water, g	Weight of saturated under vacuum sample on air, g	Volume weight d/cm^3	Water saturation % volume	Average value of volume, g/cm3	Average value of water S saturation % of volume
01.10.2011 (shungit mineral powder)	**1**		5,0	572,20	576,93	350,73	577,54	2,53	2,36	2,55	2,66
		1-2 (B)	5,1	920,72	927,76	564,87	933,41	2,54	3,50		
		1-3 (B)	5,0	972,90	976,12	599,15	980,86	2,58	2,11		

	3	**3-1 (B)**	5,3	967,88	970,26	593,25	974,21	2,57	1,68	2,57	1,20
		3-2 (B)	5,8	973,60	976,79	598,33	978,36	2,57	1,26		
		3-3 (B)	5,5	1169,82	1171,60	714,53	1172,83	2,56	0,66		
	4	**4-1 (B)**	5,0	902,55	905,24	555,93	906,09	2,58	1,01	2,55	2,00
		4-2 (B)	5,3	1041,18	1044,03	633,36	1048,90	2,54	1,88		
		4-3 (B)	5,1	879,19	884,64	537,99	889,94	2,54	3,10		
01.10.2011 (lime mineral powder)	**5**	**5-1 (B)**	5,1	868,72	871,10	535,43	874,29	2,59	1,66	2,55	2,06
		5-2 (B)	5,0	1152,31	1156,71	696,29	1163,64	2,50	2,46		
		5-3 (B)	5,0	871,29	872,98	532,26	877,39	2,56	1,79		
	6	**6-1 (B)**	5,2	909,79	911,48	561,92	914,27	2,60	1,28	2,58	1,04
		6-2 (B)	5,7	1420,38	1422,85	868,50	1424,85	2,56	0,81		
		6-3 (B)	5,7	1363,83	1366,46	830,84	1369,52	2,55	1,06		

Table 9: Phisical-mechanical properties of pavement samples on plot and control sections after two years of operation

Date of testing	Sample number (kern)	Place of sampling	Thickness of a layaer (upper, lower)		Pavement samples								
			project.	factual.	Weight of dry sample on air, g	Weight of dry sample on air after 30 min keeping in water, g	Weight of sample in water after 30 min keeping in water, g ter, gr	Weight of saturated under vacuum sample on air, g	Weight of Weight of saturated under Vacuum sample in water, g water, gr	Volume of dry sample sm^3	Volume of saturated under	Volume weight, g/cm^3	Saturation, % of volume
05.07. 2013					**Section 1. (based on shungit mineral powder)**								
		1-1 (B)		6,1	1132,58	1135,04	688,48	1146,32				2,54	3,08
		1-2 (B)		5,8	1115,93	1118,11	675,82	1130,82				2,52	3,37
		1-3 (B)		6,1	1129,25	1133,46	689,63	1141,36				2,54	2,73
		2-1 (B)		5,2	984,04	986,34	602,15	992,24				2,56	2,13
		2-2 (B)		7,0	1212,76	1214,56	737,57	1228,03				2,54	3,20

		2-3 (B)		5,2	976,06	977,20	589,79	989,24				2,52	3,40
		3-1 (B)		5,7	1123,40	1125,21	682,99	1135,43				2,54	2,72
		3-2 (B)		5,6	1090,22	1092,61	666,90	1097,43				2,56	1,69
		3-3 (B)		5,2	1034,28	1036,48	630,28	1042,32				2,55	1,98
					Section 2. (based on lime mineral powder)								
		5-1 (B)		4,5	953,05	954,79	577,42	963,32				2,53	2,72
		5-2 (B)		4,5	938,45	939,85	568,41	951,14				2,53	3,42
		5-3 (B)		4,5	950,41	952,39	578,47	959,41				2,54	2,41
		5-4 (B)		5,2	1019,13	1021,43	618,34	1029,64				2,53	2,61
		5-5 (B)		4,7	986,46	987,69	597,91	999,86				2,53	3,44
		5-6 (B)		6,1	1075,43	1077,10	655,02	1085,28				2,55	2,33

CONCLUSIONS

1. At designing the proportions of shungit containing crushed stone mastic the amount of stabilized admixture could be reduced by50% from the recommended by State Standard.
2. For crushed stone mastic the grade of crushed stone from igneous and metamorphic rock on crushability should not be than less 1200kg/m^2, from sedimentary rock , gravel and metallurgical slags – not less than 1000, the crushed stone grade on abradability is I 1 (Russian variant -И I). Crushed stone grade on frost resistance should not be below F 50.
3. Grain proportion of lamellar form in crushed stone should not be more than 15% in mass.
4. For crushed stone mastic the sand from siftings of rock crushing should meet the requirements of State Standard; sand strength grade is not lower than 1000; clay particles proportion defined by the method of swelling, is not more than 0,5, and the total proportion of grains is smaller than 0,16 mm (including slime and clay fractions) in sand from crushing siftings is not normalized.
5. For mixture preparation oil road viscous bitumen, and also polymeric-bitumen binding materials and modified bitumen according to technical documents should be applied. Optimal amount of bitumen should be specified according to the results of crushed stone mastic mixture
6. The duration of mixing is to specified according to the passport data of asphalt concrete unit and then define according to the results of trial batch. Mixing unit should provide the accurate needed batch of components.
7. The duration of transportation of crushed stone mastic mix is specified according to the conditions of providing the necessary temperature while placing. It is better to use road concrete mix reloader to protect granulometric and temperature segregation.

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