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Voronezh State University of Architecture and Civil Engineering
D. Sc. in Engineering, Prof., Head of Dept. of Road Construction and Operation
Vl. P. Podolsky
Ph. D. In Engineering of Dept. of Road Construction and Operation
D. I. Chernousov
Ph. D. in Engineering, Assoc. Prof. of Dept. of Technology of Building Products and Structures
S. M. Usachyov
Russia, Voronezh, tel.: 8-920-429-35-15; e-mail: ecodor@bk.ru

Vl. P. Podolsky, D. I. Chernousov, S. M. Usachyov

A STUDY OF BITUMINOUS SHUNGITE BINDER ON THE SCANNING MICROSCOPE

Statement of the problem. The results of domestic and foreign studies of schungite and fullerenes are analyzed. It is suggested that based on them new technologies could be developed.
Results. The images of surfaces of fine-dispersed mineral schungite and limestone powders are obtained with the use of the scanning microscope NanoEducator. Organic binder composites are investigated. The obtained data show the correlation between roughness of the surface of these materials and their fractal dimension. The laboratory tests show that schungite with its high absorptive capacity with regard to bitumen contributes to its structuring.
Conclusions. The possible application of schungite mineral powder in the preparation of the asphalt and bitumen mixture is proved. It is found that interaction of bitumen with fine-dispersed schungite particles provides formation of a stable asphalt concrete structure with predominant closed pores. The application of schungite mineral powder provides higher operational characteristics of road pavement.

Keywords: schungite, angstrom, asphalt concrete, fullerenes, carbon, mineral powder, nanolevel, globule, fractal dimension, cluster, composite.

Introduction

Shungite is a black rock (“aspid” rock) that got its name after a place of Shungite in Karelia. Massive chunks of this mineral come out at the Onega shore near the settlement of Tolvuya. There are five known shungite deposits in the Onezhskaya area. They are namely Nizgozerskoe, Shungskoe, Myagrozerskoe, Krasnaya Selga. Their raw materials are used in the manufacturing of shungite as a lightweight concrete filler.

Semen Tsipurskiy, a Russian born American scholar at the University of Arizona brought forward the uniqueness of the carbon contained in shungite based on the research of Karelian shungite. Only in shungite does it evenly distribute as conglomerates — globules — of 200—500 angstroms in size. Scientists suggest that it is them that are capable of releasing into water in a considerable amount, particularly from a ground shungite mass. Shungite is thought to be about two billion years of age. This is another secret it holds as back then there were no forests on Earth and a carbon containing rock would not generate in an anoxic environment.

Carbon (C), which is a second period element of group IV of Mendeleev's periodic table, is the only element whose valence and coordination number are identical. Thanks to the above, carbon can combine with any number of atoms in a chain with whatever number of multiple bonds and in whatever combination.

The work by Robert F. Kerl and Richard E. Smalley was of fundamental importance. It looked at a hollow carbon molecule as a cluster with 60 atoms in it [1]. This is how a structure of 60 carbon atoms (C_{60}) was theoretically computed.

The most stable structure of a spherical envelope is the combination of a pentagon and a hexagon. Using thermal decomposition the scholars succeeded in synthesing an all-new substance whose molecules had a spherical shape. This is how fullerenes which are now a growing focus of scientific interest came about (Fig. 1). The term is credited to the American architect Buckminster Fuller who applied these structures in the construction of dome buildings [2].

So far the scholars have failed to figure out how fullerene emerged in Karelian shungite but obviously microelements (Fe, Ni, Ti, Ag, etc.) play a crucial part.

At the moment there are various combinations of fullerene molecules with a large number of hydroxyl groups synthesized. The scheme of this molecule is given in Fig. 2.

There is a chance various organic compounds could be synthesized using fullerenes. That is why the fact that shungite has now been brought to the world’s attention can bring in new technologies, provide a better understanding of the world around us, give rise to new fields of science and industry which emerge central to the development of civilization. There is no doubt the research undertaken at the laboratory of Voronezh State University of Architecture and Civil Engineering and Mosavtodor into the use of shungite mineral powder in asphalt and concrete mixes is of crucial importance.

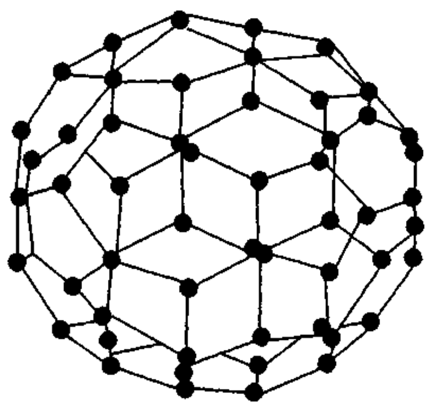

Fig. 1. Structure of a fullerene molecule C_{60}

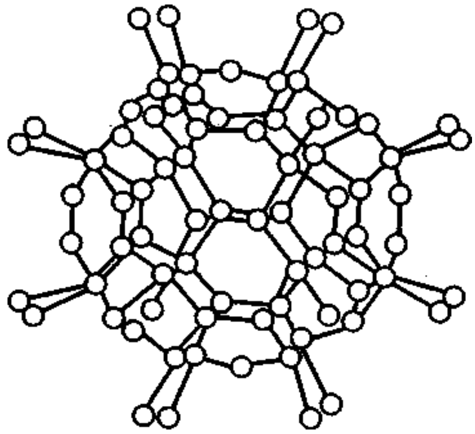

Fig. 2. Chemical makeup of a water-soluble fullerene which is a molecule C_{60} with radicals (OH) attached to it

1. Characteristics of the scanning probe microscope NanoEducator

In order to study the influence of the state of the surface of particles of shungite mineral powder on the properties of the asphalt binder at the VSUACE a number of studies were carried out on the scanning probe microscope NanoEducator which is designed to visualize, monitor and modify substances with micro and nanolevel spatial resolution (Table 1).

Table 1

Characteristics of the scanning probe microscope NanoEducator

Parameters	Quantitative characteristics
Scan modes	ACM, CTM, lithography
Scan area	70×70×10 mkm
Spatial resolution X-Y Z	~ 50 nm ~2 nm (depending on the radius of curvature of the probe)
Minimum scan pitch	10 nm
Scanning current	100—200 nA
Radius of curvature of the probe	10—100 nm
Scanning time	30—40 min (depending on the scanning area)
Warm up time (alignment time)	No more than 10 min
Size of the examined model	12×12 mm
Height of the model	No more than 5 mm

End of Table 1

Operational conditions	Quantitative characteristics
Temperature of the environment	(25 ±5) ºC
Relative humidity	No more than 60 %
Atmospheric pressure	(760 ±30) mm Hg
Electric network with the voltage with the frequency of	220 V 50 Hz
Grounding	

A set of the scanning probe microscope (SPM) NanoEducator contains a probe tip, electronics, video camera, interface cable, controlling computer, tip etching device, as well as a set of test samples, active storage and tools. Mac OS X software is utilized.

The samples were prepared for scanning in the following way:

1) pressing of disperse powder like material into bricks of 10×10×5 mm;
2) coating of a disperse powder like material on the substrate (adhesive tape).

Prior to the experiment sample caliber grids with the height of the step of 21 to 500 nm (±1.2—2.5 nm) and period of (3.0 ±0.01) mkm. Following that the sample was attached to the magnet substrate and was placed on the magnet table in the probe tip. After that an area was selected to research and the surface was scanned.

2. Study of the surface of fine dispersed mineral powders and bitumen

At stage 1 mineral powders of chalk flour, shungite and bitumen binder were examined. The evaluation of the surfaces of fine dispersed mineral particles has great implications as spalling, defects and microcracks give rise to a dramatic interior friction and thus to a better connection between the organic binder and mineral powder.

The above experiment showed that chalk flour (Fig. 3) is known to have a complex surface relief with lots of peaks and hollows. The height difference ranged from 371 to +429 nm in the scanning area of 8.5×8.5 mkm. The examined surface revealed some clear peaks (light areas) and hollows (dark areas). The roughness of the surface 0.43 mkm. Fractal dimension of the surface is D = 1.73.

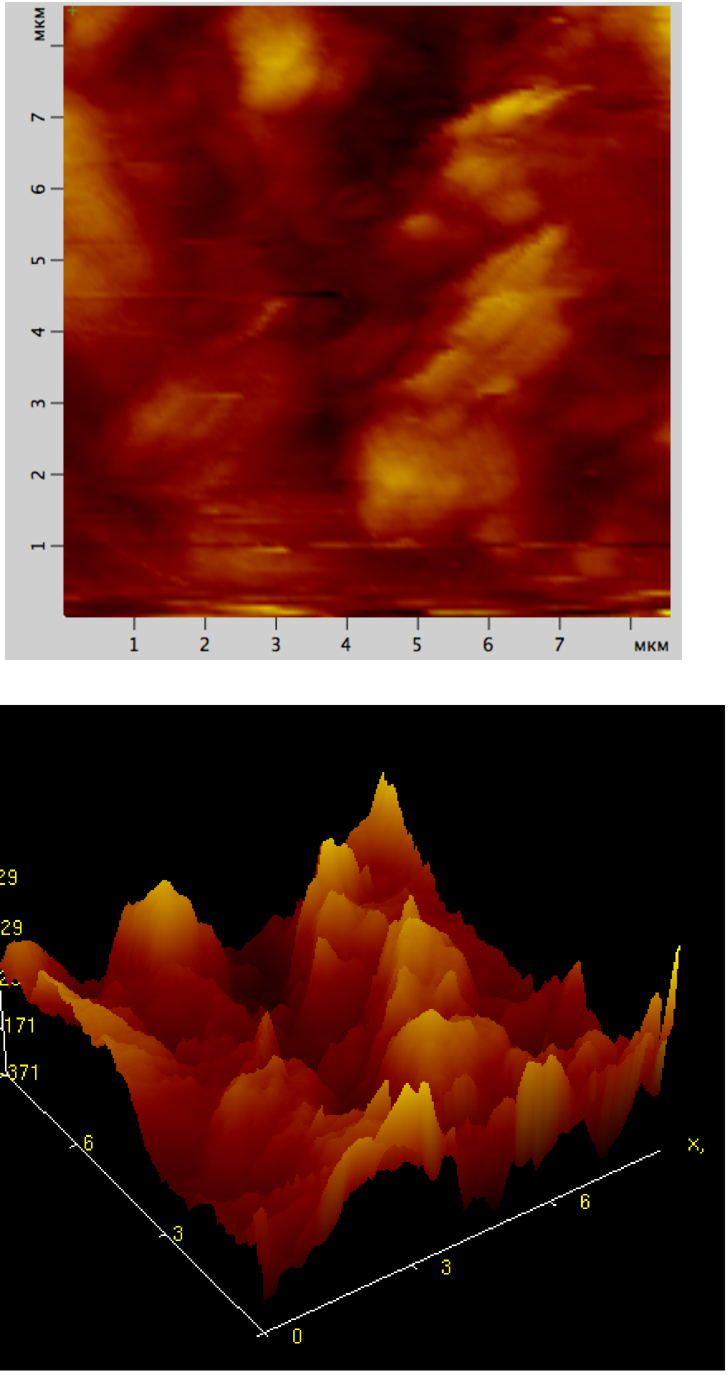

Fig. 3. 2D and 3D images o the surface of chalk flour

The structure of shungite surface looks in a different way (Fig. 4) and has a less complex relief in the area of 9.0×9.0 mkm. The roughness of the surface is 0.46 mkm and the total height difference ranged from –342 to +457 nm. Fractal dimension of the surface is D = 1.43.

Such a structure can be accounted for by a more dense structure of powder associated with its high limit surface and particle aggregation.

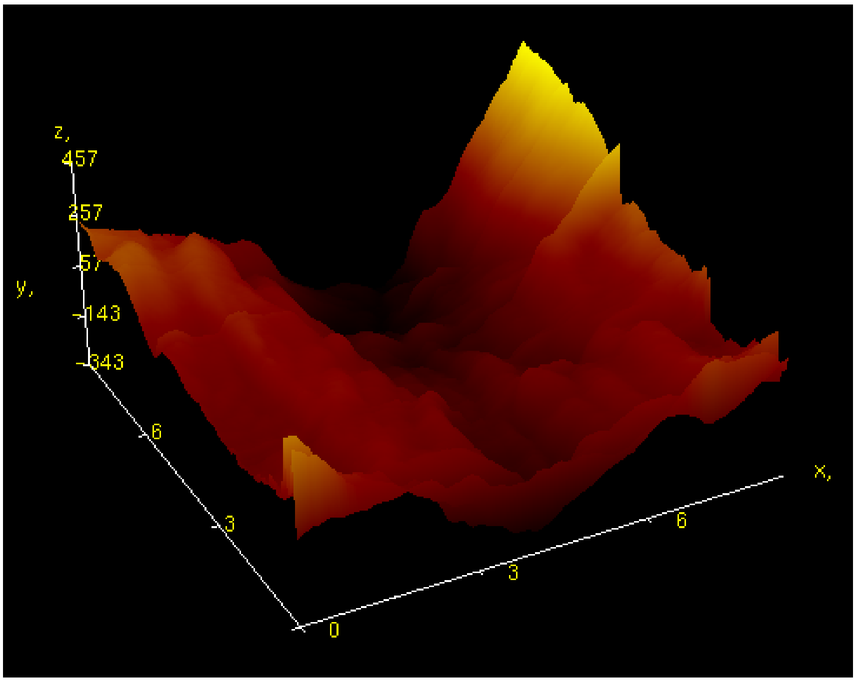

Fig. 4. 3D image of shungite surface

The organic binder (bitumen) has a fairly even homogeneous surface with no defects in the structure (Fig. 5). The scan of the sample is 9.5×9.5 mkm in size, the height difference ranges from -821 to +820 nm. Fractal dimension of the surface is D =1.97.

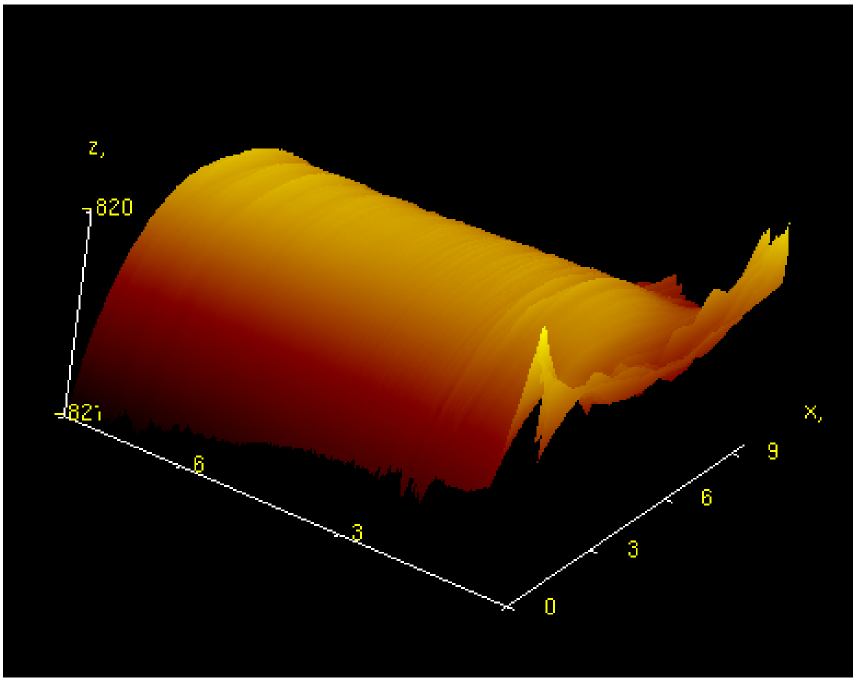

Fig. 5. 3D image of shungite surface

3. Results of scanning of the bitumen and shungite composite

At Stage 2 mixed systems were surveyed. The results of the asphalt binder scanning reveal the interaction between shungite and the organic binder (Fig. 6).

Thus, while combining of initial components in the *n*: *m* ratio are averaged (Fig. 7). It can therefore be said that shungite with its high absorption activity with regard to the organic binder contributes to its structuring. A bitumen particle penetrates the porous space of shungite and fills it. The maximum roughness of the asphalt binder with shungite is 0.027 mkm (the scan is 5.0×5.0 mkm). Fractal dimension of the surface is D = 1.64.

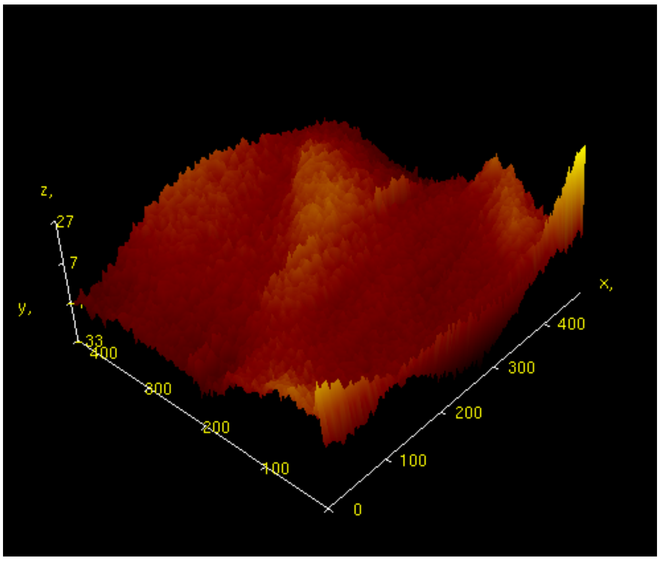

Fig. 6. 3D image of the surface of "bitumen-shungite"

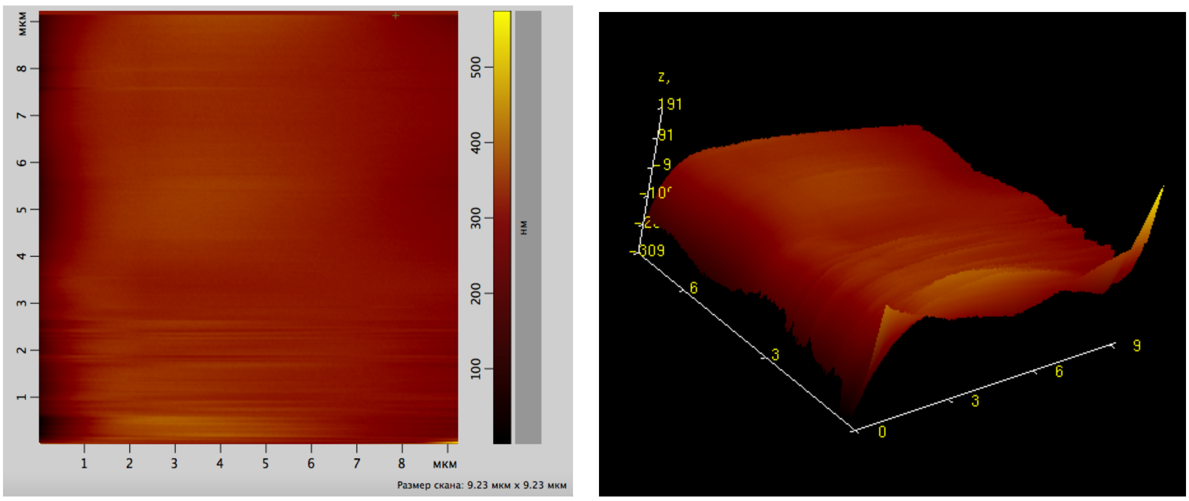

Fig. 7. 2D- and 3D images of the surface
of the "limestone-bitumen" system

The characteristics of the systems in question are identified in Table 2 and Fig. 8.

Table 2

Major characteristics of the materials

Type of the material	Quantitative characteristics	
	Roughness, mkm	Fractal dimension of the surface *D*
Limestone flour	0.43	1.73
Shungite	0.46	1.43
Bitumen	0	1.97
Asphalt binder (bitumen+shungite)	0.027	1.64

The obtained data suggest there is the correlation between the indicators of roughness and fractal dimension of the surface. The less rough the surface is, the closer the values of fractal dimension of the surface are to “2”, i. e. the material is more dense and homogeneous.

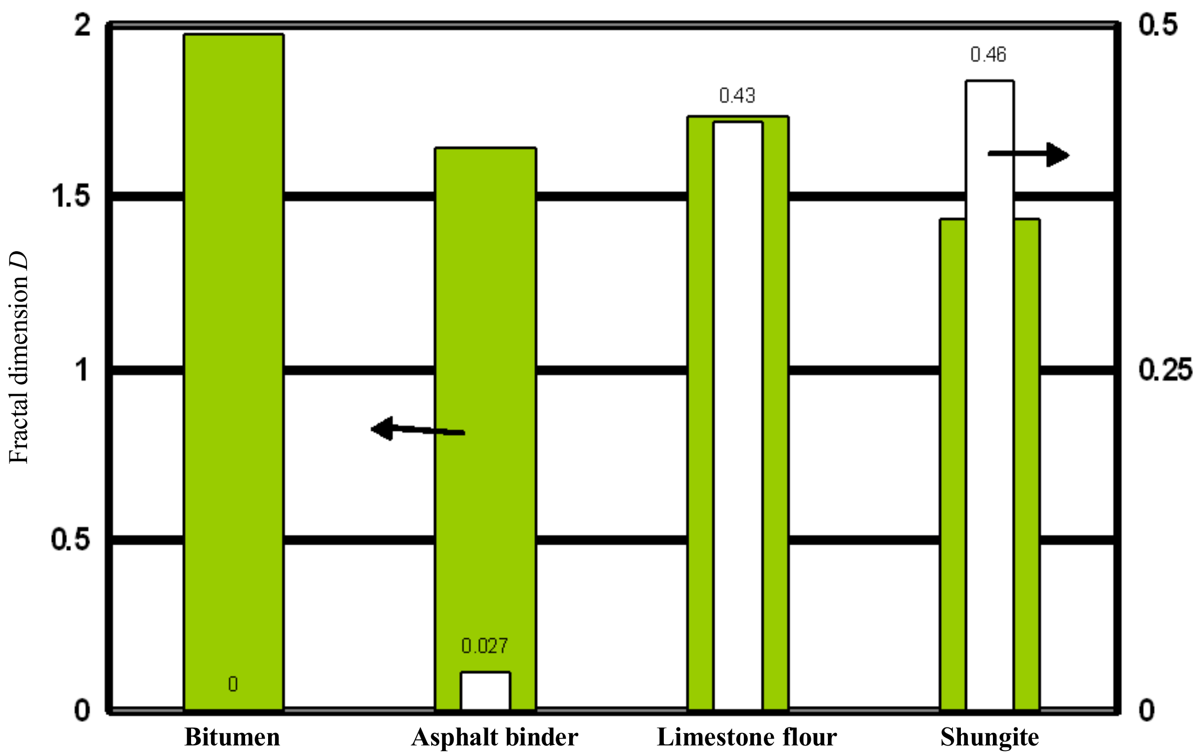

Fig. 8. Correlation of the indicators of roughness and fractal dimension of the surface

Conclusions

1. Particles of mineral powder from shungite and limestone have been compared for the first time using the scanning probe microscopy.
2. It was found out the interaction between bitumen and mineral powder particles from shungite give rise to the stable structure of asphalt and concrete with predominant isolated pores.
3. The research results proved it possible to use shungite as mineral powder.
4. It was proved that mineral powder from shungite contributes to the structuring of bitumen, which promotes physical and mechanical properties of the asphalt binder compared to limestone powder.

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