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RESEARCH OF SHEAR AND CRACK RESISTANCE OF ASPHALT CONCRETE WITH POROUS MINERAL FILLERS DMITRIY ALEKSEEVICH KUZNETSOV

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Abstract.

In work are detected peculiarities of use of porous disperse fillers of road asphalt concrete. For research was accepted keramzite dust, limestone and zeolite-containing mineral fillers. For estimation of their impact on characteristics of asphalt concrete were modeled diverse technological and operational factors impacting on material, both while its preparation and in process of operation in coating of automobile road. Shear resistance, crack resistance and corrosion resistance of asphalt concrete were researched, because these characteristics are causing a significant impact on durability of road asphalt concrete coatings. Conducted researches shown that porous fillers cause stronger structuring impact on bitumen. Besides, bitumen can be modified by cost of denudation of its most active components, asphaltenes and stable radicals that can interact with mineral material with formation of chemical linkage that would lead to strengthening of structural linkages and increase of coating's durability.

Key words. Asphalt concrete, zeolite, porous mineral fillers, shear resistance

Introduction. At contemporary stage of development of asphalt concrete technology the problem of further improvement of its properties in many ways is connected with substantial change of its structure (including bitumen structure too). In particular, the change of conditions of interaction of mineral and binding materials, in result of which between them appear chemical linkages, can approximate the asphalt concrete to condensation structures differing by higher strength. A big role in formation of asphalt concrete structure is played by structure of materials that form the mineral carcass. One of the leading roles in provision on strong structure of asphalt concrete is played by mineral filler. At present time a significant interest is represented by use of porous mineral materials in composition of asphalt concrete. Researches of possibility of their application as mineral filler for road construction branch are conducted [1-5].

Major part. An important element of interaction of bitumen with porous mineral fillers is the selective filtration of bitumen. In porous materials are concentrating a significant quantity of resins in surface micro-pores, and a part of oils, by cost of selective diffusion penetrates inside of material. Therefore, at application of porous materials adsorption layers of bitumen on surface of particles are partially depleted of resins and oils. At this,due to depletion of bitumen of oils,would occur the increase of bitumen viscosity and, therefore, strength of mixture too. Some researchers think that depletion of organic binder of oils would promote acceleration of aging process of organic binder, and therefore, shortening of service life of road coating. Others note that the result of selective filtration of oils inside of pores would be disclosure of most active components of bitumen, hidden under this inert housing. In result of this bitumen would be modified by cost of denudation of its most active components, asphaltenes and stable radicals that can interact with mineral material with formation of chemical linkage that would lead to strengthening of structural linkages and increase of coating's durability. The surface of porous mineral filler is characterized by very developed system of micro-pores and, as result, presence on its surface of micro-scaliness in for of ribs and peaks, which should promote larger cohesion of mineral material with organic binder. Besides, use of porous mineral fillers, according to a range of researches, would promote increase of shear resistance and crack resistance of asphalt concrete coatings which became especially actual for roads, operating at high summer temperatures with high transport loads. Therefore, the increase of asphalt concrete quality by cost of use in its composition of porous technogene mineral filler represents a certain scientific and practical interest. In this work are presented results of research of fine-disperse keramzite and zeolite from the point of view of their use in composition of asphalt concrete. For conduction of research were used mineral fillers from limestone of Yelets deposit, fine-disperse keramzite and zeolite of Holinskoye deposit, granite gravel and fines pf Yantsevskiy granite open pit, Ukraine, bitumen road viscous БНД 60/90 of Saratov oil-processing plant. It is known that interaction of mineral filler with bitumen is stipulated by physical-chemical processes occurring at limit of division bitumen-mineral material, due to which at the surface of mineral particles is formed a thin bitumen film, not only covering them but also capable to bing with them strongly [6-8]. Linkages emerging between bitumen and mineral particles surface have a first degree significance for properties of asphalt concrete. That's why the most important characteristic of mineral filler is its capability to strong cohesion with binder [9, 10]. Activity of mineral filler at interaction with bitumen was studied by value of adsorption of bitumen by fillers from benzol solutions of different concentrations, and also by value of desorption of bitumen from them. The amount of bitumen chemically linked to surface of mineral filler was determined by difference of amount of adsorption and desorption of adsorbed bitumen, By amount of bitumen left on surface of mineral particles after desorption was judged the activity of mineral material surface. Amounts of adsorption and desorption are characterizing the activity of processes of mineral materials interaction with organic binder. Desorption is conducted in device of Soxhlet by pure benzol up to complete clarification of solvent.

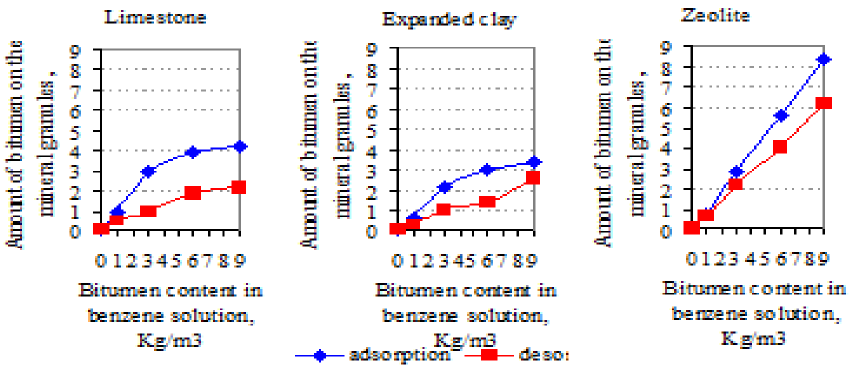


Figure 1 - Indexes of adsorption - desorption of bitumen on surface of mineral fillers.

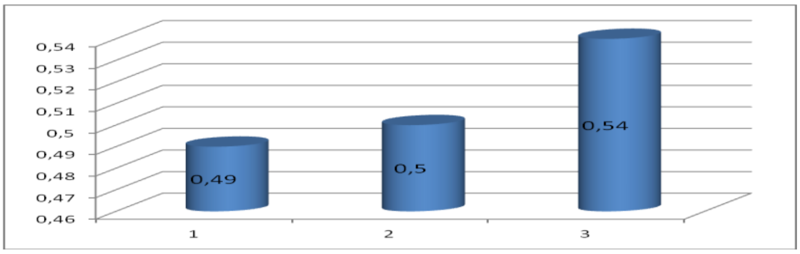
As can be seen from figure 1, the most active adsorption of bitumen components occurs on surface of zeolite. So, at concentration of bitumen in 9% solution the amount of its adsorption by surface of zeolite is $8.55*10^{-3}$ KGbit/KGpores, and by surface of limestone and keramzite $4.10*10^{-3}$ KGbit/KGpores and $3.30*10^{-3}$ KGbit/KGpores. It can be explained by high porosity of filler and, obviously, by a large quantity of adsorption centers on its surface, capable to adsorb components of bitumen. Capillary-porous structure of mineral grains at other equal conditions significantly increases the amount of adsorbed bitumen. Maximum desorption of adsorbed layer of binder occurs from surface of limestone and zeolite. However even after desorption on surface of zeolite remains more bitumen than on surface of limestone and keramzite. After desorption the quantity of organic binder remained on surface of zeolite was $6.25*10^{-3}$ KGbit/KGpores, and on surface of limestone and keramzite $2.1*10^{-3}$ KGbit/KGpores and $2.7*10^{-3}$ KGbit/KGpores. For study of impact of researched filler on properties of composite were prepared asphalt concrete samples of B type. Results of tests are shown in table 1. Strength characteristics of asphalt concrete with use of zeolite is higher than at use of limestone and keramzite. However, the task of creation of asphalt concrete, resistant to formation of deformations at maximal temperatures is inextricably entwined with preservation of resistance to cracks formation in winter period, i.e., with preservation of necessary deformability. Samples of asphalt concrete on keramzite filler at temperature of 50°C have strength at compression a little higher than this index for asphalt concrete on limestone. Strenth at compression at temperature of 50°C is an indirect index of shear resistance of organic-mineral composite. That's why, basing on received results, we can suggest that at operation of road coating in summer time the risk of occurrence of shearing deformations in form of waves, calluses, shears on asphalt concrete on keramzite filler would be a little less than in asphalt concrete on limestone. At comparison of such index as limit of strength at compression at temperature of 0°C is seen that the lowest strength have samples of asphalt-concrete on zeolite filler. The limit of strength at compression at temperature of 0°C is considered to be an indirect index of cracks formation at negative temperatures. That's why the lesser this index is, the lowed should be the probability of cracks formation at negative temperatures, in result of higher plasticity of asphalt concrete.

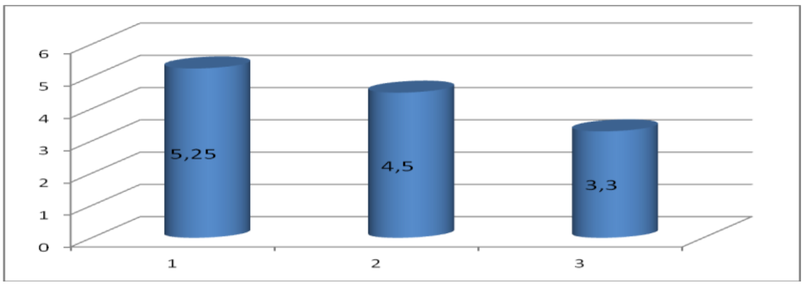
Table 1: Physical-mechanical characteristics of asphalt concrete with porous mineral fillers.

Indexes	Requirements of GOST	Mineral filler		
		Limestone	Keramzite	Zeolite
Strength limit at compression, MPa, at:				
+20° C	2.2	4.9	4.8	5.5
+50° C	1.0	2.0	2.4	3.0
0° C	12	10.5	10.8	9.8
Water resistance	0.85 at least	0.90	0.92	0.94
Water saturation, %	1.5-4.0	2.2	3.3	2.9
Bulking, %		0.04	0.4	0.3
Lengthy water resistance	0.7 at least	0.83	0.82	0.86

Important characteristics of road composite are indexes of coefficients of heat resistance and crack resistance. These indexes determine the degree of stability of strength characteristics of asphalt concrete at change of temperature. As is known, the drawback of asphalt concrete is a great dependence of its property on temperature. At positive temperature the asphalt concrete has properties of viscous-plastic material, and at negative - of elastic one. That's why is important that at changes of temperature the road composite would preserve its strength characteristics without substantial changes.

a)





b)

Figure 2 - Indexes of coefficients of heat resistance (a), crack resistance (b) of asphalt concrete with mineral filler:

1 - limestone; 2 - keramzite; 3 - zeolite

Indexes of coefficient of heat resistance of asphalt concrete with zeolite filler are exceeding the similar index of road composite on limestone for 9.2% and keramzite for 7.4%.

Index of coefficient of crack resistance of road composite on limestone is higer thamn this index in samples of asphalt concrete on keramzite for 14.3% and zeolite for 37.1%.

Analyzing the received proportions we can conclude that the road composite with zeolite is distinctive for more stability of properties at changes of temperature by comparison to asphalt concrete on both limestone and keramzite, and, therefore, longer service life of road coating too.

Durability of road asphalt concrete coatings to a large degree is determined by shear resistance of asphalt concrete in summer time and its temperature crack resistance in winter. These qualities of asphalt concrete can be estimated by strength limits at temperature of +50 and 0°C. However, increase of strength of asphalt concrete is usually accompanied by reduction of its crack resistance in period of negative temperatures.

That's why shear resistance, crack resistance and corrosion resistance of asphalt concrete were researched, because these characteristics are causing a significant impact on durability of road asphalt concrete coatings.

Crack-resistance of asphalt concrete was estimated by limit of rupture strength at splitting. Results of tests are shown in Figure 3.

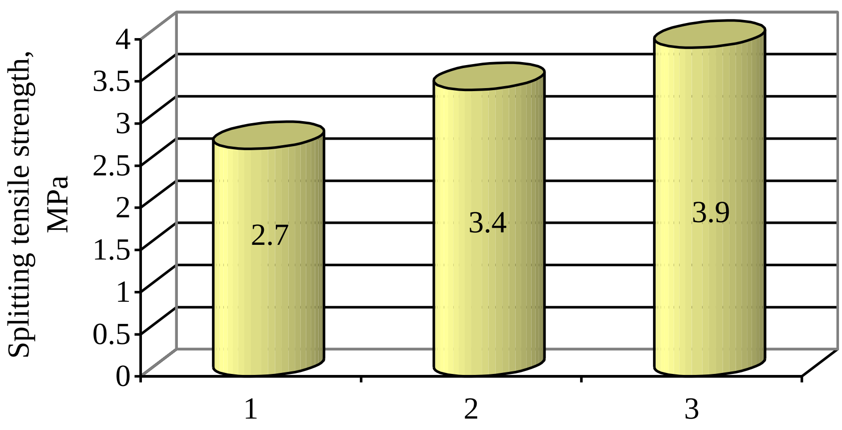


Figure 3- Limit of rupture strength of asphalt concrete at splitting

with mineral fillers: 1 -zeolite; 2 - limestone; 3 - keramzite

For estimation of shear resistance of asphalt concrete were determined maximum loads and respective extreme deformations of standard cylindrical samples at two deflected modes: at one-axis compression and at compression by scheme of Marshall. Then was calculated the laboratory index of cohesion at shear of asphalt concrete samples on researched materials.

Table 2: Indexes of shear resistance of asphalt concrete.

Mineral fillers	Coefficient of internal friction of asphalt concrete (tgφ), MPa	Index of cohesion at shear ($C_л$), MPa
Limestone	0.85	0.7
Keramzite	0.82	0.76
Zeolite	0.91	1.5

Research of crack and shear resistance of asphalt concrete allowed to establish that at application of keramzite dust and limestone mineral filler these indexes are close, and at use of zeolite they are higher, which is the evidence of the fact that this mineral filler allows to preserve the stability of properties of asphalt concrete at changes of temperature from 5 to +50C better.

Corrosion resistance of asphalt concrete was estimated by lengthy water resistance and frost resistance, up to 50 cycles of freezing-thawing.

Test of asphalt concrete for frost resistance shown that samples with mineral filler from zeolite have higher indexes of frost resistance than ones on limestone and keramzite. After 15 freezing-thawing cycles the drop of strength of road composite relatively to initial strength was: for samples on keramzite - 57%, on limestone - 33.8%, on zeolite - 9.2%. At completion of tests the reduction of strength of asphalt concrete samples with filler of keramzite was 62.6%, on limestone - 45%, and on zeolite - 22.2%.

Changes of strength of asphalt concrete after 0, 25 and 50 cycles of freezing and thawing are shown in Figure 4.

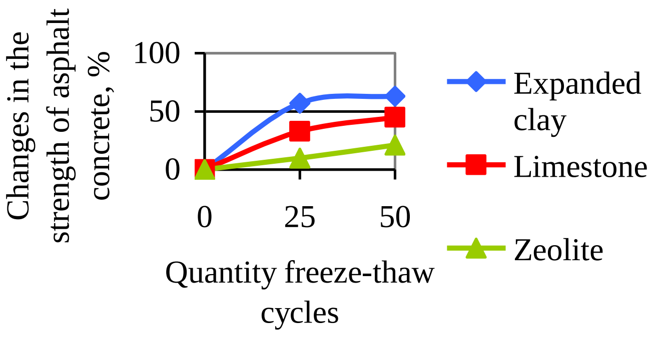


Figure 4 - Changes of strength of asphalt concrete at compression, after 0. 25 and 50 cycles of freezing and thawing with researched mineral fillers

High indexes of coefficients of lengthy frost resistance confirm previously received results on formation at border of division of phases bitumen-filler of stable linkage capable to resist the action of water. Experience of operation of asphalt concrete coatings had shown that they are destroyed especially intensely in period of lengthy moisturizing which were preceded by significant quantity of alternating sign temperature fluctuations. That's why the application of asphalt concretes, more resistant to water impact, is one of the most important factors promoting increasing of road coatings service life. On basis of received results on determination of frost resistance of asphalt concrete on zeolite filler within all period of testing has a sufficiently high indexes of corrosion resistance that asphalt concrete on fillers of limestone and keramzite. Received experimental data confirms that interaction of binder with research of porous filler, especially zeolite, goes on more actively. Peculiarities of interaction of porous mineral materials with bitumen results in the fact that linkage between mineral particles, giong through thin layers of viscous bitumen, become less elastic and more stable in regard of temperature. That's why the informative test, allowing to receive adequate picture of elasticity or fragility of bitumen veins on grains of filler, would be the research of shear and crack resistance of asphalt concrete after alternating freezing-thawing.

Table 3: Indexes of shear resistance of asphalt concrete after cycles of freezing-thawing of samples.

Mineral filler	Coefficient of internal friction of asphalt concrete (tgφ), MPa			Index of cohesion at shear ($C_л$), MPa		
	Cycles of freezing and thawing					
	0	25	50	0	25	50
Zeolite	0.91	0.85	0.80	1.5	1.30	0.81
Lime stone	0.85	0.80	0.65	0.70	0.44	0.25
Keramzite	0.82	0.64	0.53	0.76	0.68	0.30

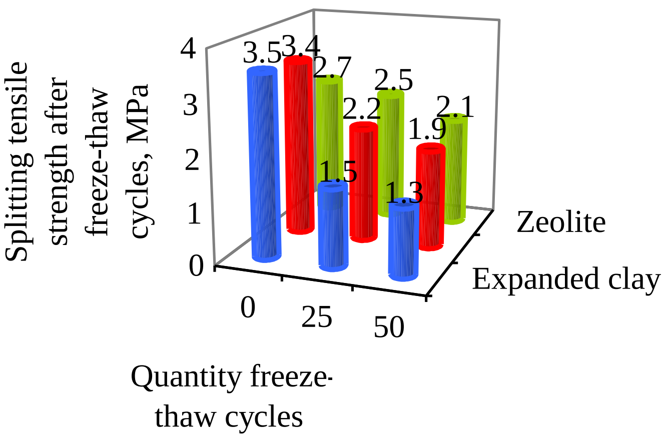


Figure 5 - Limit of rupture strength of asphalt concrete at splitting after test for frost resistance of asphalt concrete.

According to expectations, the minimum change of indexes after 50 cycles of test is characteristic for composition of asphalt concrete on zeolite, which can be the evidence of preservation of binder elasticity.

Summary. Therefore, conducted researches shown that porous fillers cause stronger structuring impact on bitumen. Besides, bitumen can be modified by cost of denudation of its most active components, asphaltenes and stable radicals that can interact with mineral material with formation of chemical linkage that would lead to strengthening of structural linkages and increase of coating's durability.

At application of zeolite as mineral filler the stability of physical-mechanical characteristics of asphalt concrete at change of temperature of environment and coating improves.

Conclusions. In result of conducted researches were detected peculiarities of use of porous disperse fillers of road asphalt concrete.

The structuring ability of porous mineral fillers is studied, and their significant impact in strengthening of system bitumen-mineral filler structure is shown.

The impact of zeolite-containing mineral filler and keramzite dust on shear resistance and crack resistance of asphalt concrete at modeling of diverse technological and operational factors is estimated.

In work is shown that porous mineral fillers can be an effective raw material for production of asphalt concrete mixtures.

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