Physical and Mechanical Properties of Asphalt Concrete Modified with Activated Mineral Powders

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Abstract. The study of the properties of asphalt concrete modified with activated mineral powders is described. Mineral powders were exposed to physicochemical activation by the joint grinding of limestone with oil sludge in a ball mill in order to produce asphalt concrete samples. Modification of mineral powder grains surface can improve adsorption layer properties. This leads to a sharp increase in the adhesion between bitumen and mineral powder grains. Activated mineral powders are characterized by lower porosity, bitumen capacity and swelling. Water resistance of such samples is higher than that of non-activated powders. It has been determined that production of asphalt concrete with activated mineral powders requires 57% less bitumen than production of control samples. At the same time, the physicomechanical properties of asphalt concrete samples fully satisfy the requirements of regulatory documents.

1. Introduction
Mineral powder (MP) in the composition of asphalt plays a key role in structure creation. At a certain concentration of mineral powder in the asphalt-binding substance (ABS), a sharp decrease in the thickness of bitumen layers on the surface of mineral grains occurs, which leads to a high degree of bitumen structuring and, therefore, to hardening the bonds between the grains [1-6].

2. Objectives
Modifying the surface of mineral powder grains by treating them with surface-active substances (surfactant) makes it possible to bring together the molecular properties of the adsorption layer and the medium that the powder must fill. A thin layer of surfactant formed on the surface of mineral grains in the activation process represents a structural-mechanical barrier that simultaneously performs several functions: improves the wettability of mineral powder grains with bitumen, prevents the formation of aggregates in the structure of asphalt concrete, prevents selective filtration of bitumen components into the pores of mineral powder grains, provides mineral powder grains surface with hydrophobic properties, prevents the accumulation of moisture in the mineral grains. Thereafter, usage of activated mineral powders in asphalt concretes can significantly affect the most important structural and mechanical properties of the asphalt concrete [7-11].
3. Testing of physical and mechanical properties of asphalt concrete

Earlier studies have found that mineral powders obtained by the joint grinding of limestone and oil sludge have a higher structuring ability with respect to bitumen compared to traditionally used non-activated mineral powders [11-15].

To prove the possibility of using activated mineral powder in asphalt concrete, it was required to conduct a series of tests for compliance with GOST 52129-2003. The test results are presented in table 1.

| Name of Indicator                        | Value for MP    | GOST requirements |
|------------------------------------------|-----------------|-------------------|
| Porosity, %                              | 31,03           | 28,19             | ≤ 30              |
| Swelling of powder-bitumen samples, %    | 2,15            | 0,85              | ≤ 1,8             |
| Water resistance of powder-bitumen samples, % | 1,09            | 0,96              | not regulated     |
| Bitumen capacity, g                      | 70              | 52                | not regulated     |

Mineral powder exposed to physicochemical activation is characterized by a lower indicator of bitumen capacity. The bitumen capacity of mineral powder suspension activated by oil sludge is less than that of the initial MP by 26%. Thus, it can be assumed that in the case of activated mineral powder usage in the preparation of asphalt concrete mixtures it is possible to reduce the amount of bitumen in mixture composition.

In addition, a mixture of activated mineral powder with bitumen has a lower swelling rate. Swelling of samples with oil sludge activated powder is 2.5 times less than the rate of swelling of control samples. Water resistance of samples with activated mineral powder is also reduced in compare to this indicator of the control group of samples.

In the course of studying the physicochemical properties of mineral powders, it was shown that the physicochemical activation of mineral powder grains surface can significantly improve the technical properties of powders. So, for example, in comparison with the initial mineral powder, surfactant activated powder has a decrease in the indicator of porosity, bitumen capacity, decreases swelling of ABS. During ABS composition selection, it has been established that the usage of surfactants allows reducing the amount of binder required for the manufacture of samples. Thus, mineral powders, the surface of which was subjected to physicochemical activation, are suitable for the manufacture of asphalt concrete mixtures.

Sandy asphalt concrete was chosen to study the physicochemical characteristics of asphalt concrete, since it is the most homogeneous material. Therefore, it will show the features of the interaction of bitumen with mineral powder more clearly [7, 16-18].

Composition of dense asphalt concrete grade II, type G was selected to test the results of the study. The grain size distribution of the mineral part of asphalt concrete met the requirements of GOST 9128-2013 (Figure 1).

The amount of bitumen for samples with different mineral powders was selected individually, since activated powders are characterized by a lower value of bitumen capacity. The amount of bitumen in the mixture was 7 wt.% for control samples with limestone mineral powder and 4 wt.% for samples with oil sludge activated powder.

As previously expected, the use of activated mineral powders has made it possible to reduce the amount of binder required for the preparation of asphalt concrete mixtures. Thus, preparation of asphalt concrete mixtures with activated mineral powders requires 57% less bitumen than preparation of asphalt concrete mixtures with a control mineral powder.
Asphalt concrete mixes were prepared using a LS-AB-10 laboratory mixer, the samples were molded and tested using the IP-1000M-avto and IP-50M-avto test presses, according to GOST 12801-98 [19].

Main physicomechanical properties of asphalt concrete samples were studied, such as porosity, compressive strength, water resistance, crack resistance during splitting.

The dependence of the strength when compressing asphalt concrete samples using different mineral powders on the test temperature (0°C, 20°C, 50°C) is shown in figure 2.

It was found that compressive strength of asphalt concrete samples with activated mineral powder in its composition is lower at 20 °C and 50 °C than that of control samples. While compressive strength at 0 °C remains almost the same. Thus, compressive strength of samples with activated mineral powder is 1.1 times lower in compare to control composition at 20 °C, and 1.7 times lower at 50 °C.

Table 2.
The main physicomechanical properties of asphalt samples are presented in table 2. Despite lowered physical and mechanical properties of asphalt concrete samples modified with oil sludge activated mineral powder in compare to control samples, they meet the requirements of GOST 9128-2013. Lowered value of water saturation should be considered as a positive effect, since the limitation of this indicator in GOST 9128-2013, first of all, is connected with the prevention of binder overrun in the asphalt concrete mix. Asphalt concrete, characterized by a lower value of water saturation, will have high frost resistance and, therefore, an improved indicator of resistance to atmospheric corrosion.

| Name                                           | Normative value for asphalt concrete grade II type G GOST 9128-2013 | Mineral Powder |
|------------------------------------------------|--------------------------------------------------------------------|----------------|
|                                               | Control asphalt concrete composition                              | Oil sludge activated powder |
| Ultimate compression strength, MPa at temperature: |                                                                    |                |
| 50°C                                          | ≥ 0,9                                                             | 5,36           |
| 20°C                                          | ≥ 2,2                                                             | 7,96           |
| 0°C                                           | ≤ 10                                                              | 8,37           |
| Water resistance                              | ≥ 0,9                                                             | 1,03           |
| Crack resistance, MPa                         | 2,5 .. 6,0                                                        | 5,2            |
| Water saturation                              | 1,5 .. 4,0                                                        | 1,43           |
| Porosity of mineral part, %                   | 14 .. 19                                                          | 19,43          |

4. Conclusions
Thus, as a result of laboratory research, it has been proven that the use of the technology of physicochemical activation of mineral powders for the production of asphalt concrete is promising. Asphalt concrete with the use of activated mineral powders is characterized by improved values of water resistance and water saturation in compare to asphalt concrete with non-activated mineral powders, which will positively affect the durability of road pavements.

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