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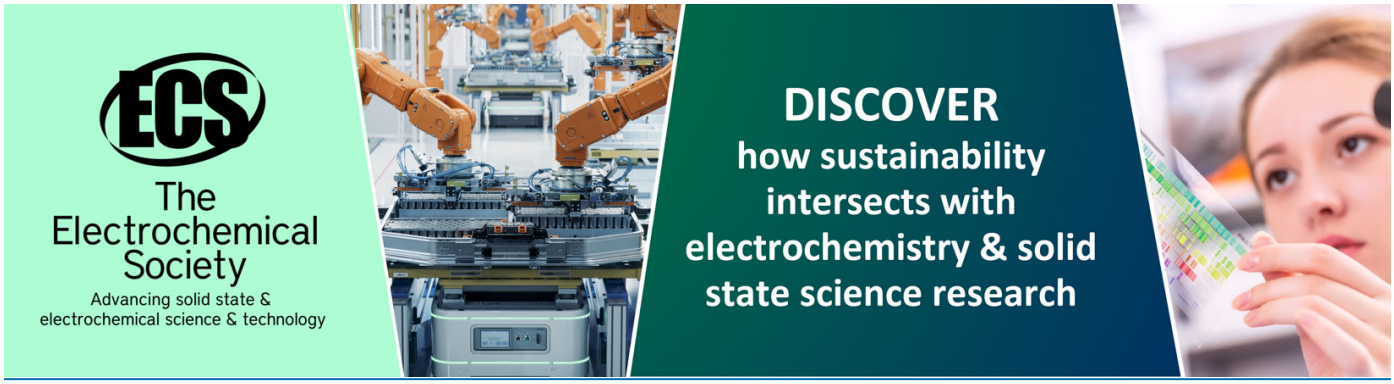

The use of waste in the composition of organic-mineral mixtures used in road construction

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Abstract. The construction of highways requires a large amount of building materials. Organo-mineral mixtures, which include asphalt concrete, are the main building material for the construction of the upper layers of the road structure. In order to reduce the cost of asphalt concrete, part of the natural mineral raw materials may be replaced by industrial waste. Previous studies show that waste from various industries in terms of their physical and mechanical properties are not inferior to natural raw materials used in road construction. When using the material resource of waste, environmental issues are additionally resolved by reducing the volume of waste disposal at landfills. The studies carried out have shown that the composition of the asphalt concrete mixture, in which drill cuttings are used, as a mineral powder, meet the requirements for asphalt concrete. Studies have shown that waste plastics HDPE and LDPE can be considered as reinforcing and modifying elements in the structure of asphalt concrete. Asphalt concrete, which includes plastic waste, meets the requirements for asphalt concrete used for road construction.

1. Introduction

Today, the road industry of Russia has important tasks: to bring the network of federal roads to the standard state, to ensure high quality coverage of the largest regional networks, to reduce the cost of construction. Reducing economic costs can be achieved through the use of industrial and consumer waste. [1-4] Previous studies show that wastes from various industries are not inferior to natural raw materials in terms of their physical, mechanical and other properties. [5-7] When using the material resource of waste, environmental issues are additionally resolved by reducing the volume of waste disposal at landfills. In the construction of highways, a significant part of the budget is allocated to the production of asphalt concrete. Asphalt concrete is the most widely used material for paving in the world. It has advantages over other materials used for the road top layer: long service life; ability to withstand heavy loads; applicability in different climatic conditions; relatively cheaper cost of construction, maintenance and repair; the best indicators of evenness and comfort for drivers; reduced requirements for the foundation device; reusability. [8-10] For its production use: crushed stone, sand, mineral powder, bitumen, various additives to improve the strength and performance characteristics of asphalt concrete. One of the options for reducing the cost of producing asphalt concrete mix is to replace natural mineral components with waste. Currently, developed and successfully applied a large

number of technologies for such replacement. Metallurgical slag, construction waste, spent molding sand and other types of industrial waste are used as mineral components. [11-14] The use of waste in the composition of an asphalt concrete mixture is possible if the physic mechanical, chemical and environmental indicators of the waste are close to the values of the component being replaced. With a large difference in indicators, the use of waste in the composition leads to a decrease in the operational and strength characteristics of the obtained asphalt concrete. Another option for the successful use of waste in the composition of asphalt concrete is the use of specific properties of waste, which can increase the strength or other characteristics of asphalt concrete. [15-18] An example is the use of polymer waste as modifiers of bitumen (to improve the adhesion of bitumen to mineral components), waste cellulose, asbestos, plastic as a reinforcing additive (to increase strength, wear resistance, resistance to rutting). [19, 20] These wastes have no chemical relationship with natural components used in asphalt concrete, but improve the characteristics of asphalt concrete due to the formation of new bonds in the structure of asphalt concrete.

Using the above mentioned principles of waste selection for use in the composition of road-building materials, two large-tonnage waste can be distinguished, which can be successfully used in the composition of asphalt concrete. These are drill cuttings (oil drilling waste) and plastic waste (low and high pressure polyethylene). Drilling cuttings contain rock and up to 5% oil. The oil content depends on the geological conditions, the technical condition of the drilling equipment, and the work culture. In this case, oil is considered as a source of light hydrocarbons capable of increasing the adhesion properties of bitumen and reducing the rate of aging of bitumen during the technological cycle of asphalt concrete production and operation. Using drill cuttings it is possible to obtain: paving slabs; curbs; concrete mixes; components for road surface; cinder blocks used in the construction of utility rooms; organo-mineral mixtures used in construction; soil-agrarian mixtures for agricultural use; ceramic brick. Based on a preliminary assessment of the physical and mechanical properties and particle size distribution, it was suggested that drill cuttings could be used as a mineral powder in asphalt concrete. At the same time, a reduction in the cost of asphalt concrete production will be achieved and the volume of accumulation of drill cuttings will decrease.

Waste plastic, when used in asphalt concrete, can play the role of a reinforcing element and bitumen modifier, which will improve the performance of asphalt concrete. Plastics based on HDPE and LDPE have a melting point sufficient to create monolithic organo-mineral structures. As previously conducted studies show, when heating and mixing the mineral part and bitumen, plastic partially passes into the bitumen melt, forming modified bitumen. The rest of the polymer is evenly distributed in the asphalt concrete layer, forming reinforcing elements in its structure. This improves the strength properties of the resulting asphalt concrete.

2. Materials and methods

Three samples of oil-based drill cuttings from different oil fields in Western Siberia were selected for research. The assessment of the possibility of using waste as a raw material for the production of building materials according to environmental indicators was determined in accordance with PND F 16.1: 2.3: 3.50-08 "Guidelines for the determination of heavy metals in farmland soils and crop products."Physicochemical characteristics of drill cuttings were determined according to: chemical oxygen consumption of water extract according to PND F 14.1: 2: 4.190-03; dry residue according to PND F 16.2.2: 2.3: 3.32-02; stiffness according to PND F 14.1 2 3.98-97; petroleum products (water-soluble) according to RD 39-0147098-015-90.

To establish the compliance of the materials obtained with the requirements of the established regulatory documents, the physical and mechanical parameters of the obtained samples were used. To determine the belonging of drill cuttings to known mineral powders, a method was used according to GOST R 52129-2003.

To determine the physical and mechanical parameters of the obtained asphalt concrete samples, we used the methodology GOST 9128-2013. For the manufacture of asphalt concrete samples, we used: crushed stone of fraction 10 - 20 (crushed stone grade M1000, crushed stone group according to the

content of flaky needle-shaped grains - 1, abrasion grade I-1, frost resistance grade F100, true crushed stone density 2.71 g/cm^3). natural sand with a fineness modulus M_k = 1.80 (true density 2.65 g/cm^3, the content of dust and clay particles 0.4% by weight); sand from the crushing screenings with a fineness modulus of M_k = 2.81 (the true density of sand from the crushing screenings is 2.78 g/cm^3, the content of clay particles is 0.36%); non-activated mineral powder MP issued in accordance with GOST 52129-2003; bitumen grade BND 60/90 produced by OOO Lukoil-Permnefteorgsintez, which meets the requirements of GOST 22245-90. All mineral materials, as well as bitumen, adopted for the design of the grain size composition of hot dense fine-grained asphalt concrete mix comply with regulatory documents, which implies the production of high quality asphalt concrete mix.

Waste generated from low and high pressure polyethylene produced in accordance with GOST 16338-85 and GOST 16337-77, respectively, was used as a polymer.stone.

3. Results and discussions

When using drill cuttings in technologies for obtaining building materials, it is necessary to study in detail its chemical composition, since the presence of impurities affects the final characteristics of the material obtained. The general composition of drill cuttings includes: water - up to 25%; cuttings - up to 60%; chlorides - 0.1 - 0.6%; heavy metals - 1 - 5%; drilling fluid reagents - 3 - 8%; other compounds - 0.3 - 0.5%. The degree of contaminants depends on the type of drilling fluid that is added during drilling. Drilling mud is a complex multicomponent dispersed system of suspension, emulsion and aerated fluids used for flushing wells while drilling. In practice, drilling fluids are used on water (industrial water, salt and hydrogel solutions, polymer, polymer-clay and clay solutions) and hydrocarbon (lime-bitumen solution, inverse emulsion) bases. In this regard, there is a wide range of physical and chemical parameters of drill cuttings from different fields.

The study of the physicochemical indicators of drill cuttings samples began with the determination of the content of heavy metals, since a significant excess of the content over the value of the maximum permissible concentration (MPC) will not allow the use in the composition of building material. The content of heavy metals in the studied samples of drill cuttings is given in table 1.

Table 1. Heavy metal content in drill cuttings samples.

Sample	Heavy metal content, mg / kg						
	Cadmium	Chromium	Nickel	Cobalt	Lead	Copper	Manganese
№1	>0.2	0.9±0.2	3.6±0.5	1.8±0.2	3.2±0.5	2.5±0.6	140±4
№2	>0.2	1.8±0.2	1.6±0.1	1.9±0.2	3.6±0.5	2.2±0.5	23±4
№3	>0.2	1.7±0.2	3.3±0.5	0.9±0.2	2.8±0.5	0.8±0.1	112±4
MPC	1.0	6.0	4.0	5.0	6.0	3.0	600

Analysis of the results of laboratory studies of samples of drill cuttings showed that there are no excess of the standards for the content of heavy metals in mobile form. This gives reason to consider drill cuttings as a raw material for the production of building materials without restrictions on the indicators of ensuring environmental safety.

To determine the physicochemical parameters, water extracts were prepared from drill cuttings samples. The research results are presented in table. 2.

Table 2. Physicochemical indicators of the investigated drill cuttings.

Sample	Determined characteristics				
	pH	COD, мг	Oil products, mg/dm^3	Dry residue, mg/dm^3	Chlorides, mg/dm^3
№1	7.0 ± 0.05	580 ± 29	1.5 ± 0.30	620 ± 62	452 ± 22
№2	6.9 ± 0.05	1300 ± 65	4.4 ± 0.9	1590 ± 159	1411 ± 70
№3	7.8 ± 0.05	444 ± 22	2.70 ± 0.9	1800 ± 180	1650 ± 82
MPC	6.5 - 9.0	30	0.05	1000	300

Physicochemical indicators of water extract from drill cuttings samples exceed the MPC values in terms of chemical oxygen demand (COD), oil products, dry residue, chlorides. The obtained characteristics make it possible to classify the drill cuttings used in the study as IV class of environmental hazard. This hazard class allows the use of drill cuttings as raw materials in the production of building materials. All three samples of drill cuttings do not contain elements that prevent their use in asphalt concrete.

Evaluation of the content of dusty particles in the composition of drill cuttings samples and their grain size composition showed that they meet the requirements of GOST R 52129-2003 and can be used as a mineral powder. In terms of their properties, the investigated drill cuttings are similar to the mineral powder of the MP-2 grade (mineral powder from non-carbonate rocks).

The study of the physical and mechanical characteristics of asphalt concrete samples in the composition, which was used dewatered drill cuttings as a mineral powder, was carried out in accordance with GOST 9128-2013. Three series of asphalt concrete samples were formed. Component composition of the asphalt concrete mixture: sand - 12.5%; crushed stone - 45.5%; crushing screening - 36%; drill cuttings - 6%; bitumen - 5.3% over 100%. The obtained asphalt concrete samples before testing are shown in figure 1.

Figure 1. Samples of asphalt concrete.

Tests were carried out to determine the values of the average density, compressive strength, water resistance, water saturation, residual porosity of the mineral part of asphalt concrete from hot mixes. The test results are shown in table. 3.

Table 3. Indicators of physical and mechanical properties of asphalt concrete samples.

Indicators	GOST requirements	Sample		
		1	2	3
Average density, g/cm^3	-	2.39	2.35	2.43
Limit compressive strength, MPa:				
R50 ºC	>1.2	1.34	1.30	1.2
R20 ºC	>2.5	2.52	2.55	2.60
R0 ºC	<11.0	10.6	9.8	10.4
Water resistance	>0.85	0.89	0.93	0.95
Water saturation,%, %	1.5-4.0	1.90	1.70	1.85
Residual porosity, %	2.5-5.0	4.4	4.0	3.2

The resulting asphalt-concrete mixture belongs to type B, I grade. According to the results of the study, it was found that all asphalt concrete samples meet the requirements of GOST 9128-2013.

Two series of asphalt concrete mixture samples were formed, which included HDPE (Sample 1) and LDPE (Sample 2) wastes as a modifier. The composition of the asphalt concrete mixture: crushed stone of fraction 10-20 mm - 46%, sand - 12%, sand from crushing screenings - 39%, mineral powder - 3%, bitumen BND 60/90 - 5%. Waste plastic, in the amount of 4%, was added to the composition in addition to over 100%. The obtained physical and mechanical characteristics of asphalt concrete are presented in table. 3.

Table 4. Physical and mechanical characteristics of asphalt concrete with the addition of plastic.

Indicators	GOST requirements	Sample 1	Sample 2
Average density, g/cm^3	-	2.4	2.3
Water saturation, %	1.5-4.0	1.8	1.7
Residual porosity, %	2.5-4.0	3.4	3.3
Limit compressive strength, MPa:			
R50 ºC	>1.2	1.5	1.6
R20 ºC	>2.5	4.9	5.0
R0 ºC	<11.0	9.6	9.9

According to the results of the study, it was found that all asphalt concrete samples with a HDPE and LDPE content of 4% meet the requirements of GOST 9128-2013.

Comparative analysis of the obtained asphalt concrete samples with the addition of drill cuttings and plastic waste showed that the use of plastic allows to obtain a higher quality asphalt concrete. Asphalt concrete modified with plastic has higher strength properties at different temperatures, which indicates high performance in summer and winter. When molding the samples, it was found that the mixture loses mobility faster than samples with drill cuttings. This indicates the increased requirements for the temperature regime, when laying such a mixture in a structural layer during the construction of a highway.

4. Summary

Drilling cuttings formed during drilling of oil fields can be considered as a raw material for the production of mineral powder for asphalt concrete. The content of oil in drill cuttings is considered a positive factor and can be used to produce activated mineral powder. Such use makes it possible to reduce the amount of bitumen in the asphalt concrete composition and to obtain significant savings in material resources. The studies carried out have shown that the composition of the asphalt concrete mixture: sand - 12.5%; crushed stone - 45.5%; crushing screening - 36%; drill cuttings - 6%; bitumen - 5.3% over 100% meet the requirements of GOST. Oil-based drill cuttings can be recommended for inclusion in the composition of asphalt concrete from 1 to 6%.

Waste plastics HDPE and LDPE can be considered as reinforcing and modifying elements in the structure of asphalt concrete. Asphalt concrete, which includes: crushed stone of fraction 10-20 mm - 46%; sand - 12%; sand from crushing screenings - 39%; mineral powder - 3%; bitumen BND 60/90 - 5% and plastic waste 4% meet the requirements of GOST for asphalt concrete. When using such an asphalt concrete mixture, it is necessary to strictly maintain the paving temperature, since a decrease in temperature sharply increases the rigidity of the mixture, reducing the compaction coefficient of the asphalt concrete.

Drilling waste and plastic waste have a positive effect on the processes of structure formation in organomineral mixtures. With their help, it is possible to obtain asphalt concrete with increased physical, mechanical and operational performance.

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