Development of technology for obtaining asphalt concrete mixture using oil sludge as an additive

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Abstract. Oil sludge is similar in composition to the composition of bitumen, which is one of the important components of asphalt concrete mixture. Therefore, oil waste can be used in the production of asphalt concrete, both as an organic binder to strengthen local soils and as a binder to produce organomineral mixtures. The use of oil sludge in road construction helps preserve natural resources, improve the environmental situation, and reduce the cost of building materials. In this work, physical and mechanical properties of asphalt concrete mixture of grade I type B were researched. To improve the performance characteristics of asphalt concrete oil sludge from oil company Zhaik Munay LLP (Uralsk) was used as an additive. Oil sludge was added to the asphalt concrete mixture in amounts of 5, 10 and 15%. When using 5% oil sludge, no significant changes in the properties of asphalt concrete are observed. An addition of 15% of oil went to the reduction of maximum efficiency during compression (0.03% by volume) and shear resistance by the efficiency of internal friction coefficient (0.01% by volume). The optimal amount is to use 10% oil sludge, at the same time, the compressive strength increases by 0.07% by volume, water resistance increases (0.02% by volume), water saturation decreases by 0.28% by volume, which has a positive effect on the quality of asphalt concrete. The properties of asphalt concrete before and after adding oil sludge were studied: compressive strength, water resistance, water saturation, shear resistance. It was concluded that it is advisable to use oil sludge as an additive. A technology for producing asphalt concrete mixture using oil sludge has been developed, which allows reducing its cost.

1 Introduction

Currently, with the development of oil industry, the problem of the formation and accumulation of large-scale waste is becoming increasingly relevant. The impact of oil waste on natural objects is due to the toxicity of extracted hydrocarbons, the content of radioactive elements in them, and a wide variety of chemicals, used in technological processes, insufficient environmental safety of the processes. The pollutants present in oil wastes are characterized by high water solubility and volatility, in addition, they themselves are solvents and can concentrate other substances. All this poses a danger of contact of oil waste with the natural environment, especially with ecological systems [1]. Oil sludge is the largest-tonnage waste from oil production and oil refining and is hazardous to the environment. During long-

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term storage, oil sludge is eventually divided into several layers, with properties characteristic of each of them [2].

The top layer is a "watercut oil product". The composition of this layer includes 70-80% oils, 6-25% asphaltenes, 7-20% resins, 1-4% paraffins. The water content does not exceed 5-8%.

The middle layer, which is relatively small in volume, is an "oil in water" emulsion. This layer contains 70-80% water and 1.5-15% mechanical impurities. The next layer consists entirely of settled mineralized water with a density of 1.01-1.19 g/cm³. The bottom layer (bottom mud) is usually a solid phase, including up to 45% organic matter, 52-88% solid mechanical impurities, including iron oxides. Since bottom mud is presented in the form of a hydrated mass, the water content in it can reach up to 25% [3].

During the extraction, further processing and transportation of crude oil, oil sludge is formed, which is subject to burial or processing. Recycling of oil sludge is one of the most important tasks of industry, as it is a valuable raw material for processing and recycling in the process of human life, subject to preliminary analysis of the feedstock and selection of optimal technology [4,5].

In sanitary and hygienic terms, oil sludge is a weakly accumulating substance that causes minor damage to liver and heart cells. As a result of technogenic impact of oil waste, a significant change in the natural state of geoecological environment occurs, a decrease in its natural protection of groundwater, activation of geochemical and geomechanical processes, and a change in the natural microbiocenosis [6,7].

The problem of the existence and study of the composition of oil sludge, as well as its methods of disposal and processing, is the subject of a number of scientific works. Thus, work is devoted to environmental monitoring of soil contamination with oil-containing waste [8]. The authors conducted experimental studies to determine the degree of toxicity of soils contaminated with petroleum products using biological test objects: the green protococcal alga Chlorella vulgaris Beijer and the crustaceans Daphnia magna Straus. The conducted studies confirm the effectiveness of using biotesting methods to determine toxic soil contamination with petroleum products.

Oil sludge is similar in composition to that of bitumen. Oil sludge, like bitumen, contains 40-60% oils, 20-40% resins, 10-25% asphaltenes, 1-3% carbenes and carboids, as well as a small amount of phenols and paraffin (up to 1%). According to their structure, bitumen belongs to complex colloidal solutions of asphaltenes and part of resins (dispersed phase) in a medium of petroleum oils (dispersion medium) [9].

The presence of a large amount of asphaltenes and resins in oil sludge makes it possible to use it in road construction as a binder that improves the quality of gravel mixture. Due to the use of oil sludge, strength increases, water absorption decreases and the cost of road surface decreases.

For example [10] developed materials for road construction using oil sludge of various origins. These include oil-soil mixture, concrete mixture, high-strength aerated concrete, asphalt concrete mixture [11], sludge concrete based on oil sludge formed during the treatment of wastewater from oil refineries and sludge from oil production [12].

The work analyzes the main methods for recycling waste from oil production. Technologies for processing oil sludge and obtaining a secondary product are considered. The possibilities of obtaining inert soil, building material, expanded clay and other materials using drill cuttings were assessed [13].

The work author studied the process of obtaining an environmentally friendly organomineral additive (OMA) by mixing a silica-containing composition with oil sludge. A method of using OMA in the production of expanded clay with low bulk density and the required strength at lower clay firing temperatures is shown. Neutralized waste can be used at waste processing plants and in the construction industry [14]. In the work, oil sludge was

used to produce expanded clay with low bulk density and high strength [15]. The work should be noted as no less interesting, where a technology for the production of gravel, crushed stone, and expanded clay was developed, which were used at drilling sites for the production of porous and dense aggregates for thermal insulation and structural concrete. A technological solution has been proposed for separating oil waste into liquid (petroleum products, water) and solid phases. Subsequent neutralization of oil-contaminated residue was carried out using a chemical method [16]. As a result of sludge disposal, filler is obtained, which is used as an additive in composite materials [17]. Montayev S.A. and colleagues developed a composite additive using oil sludge for the production of effective wall ceramics. The possibility of producing high-quality wall ceramics based on oil sludge, which serves as a surfactant, has been determined. The fundamental possibility of using oil sludge as a modifying component in the production technology of wall ceramics has been proven. This achieves not only an economic, but also an environmental effect [18].

Thus, the search for effective technologies and environmentally acceptable methods for processing oil sludge is the main task of developers, while an important task is to solve the problems of cleaning and recycling waste from the process.

The purpose of this work is to develop a method for recycling oil sludge and the possibility of using it as an additive to asphalt concrete mixtures.

2 Materials and methods

The research objects are oil sludge company "Zhaik Munay" LLP and asphalt concrete grade I type B. One of the important indicators of oil sludge is radioactivity. Energy carriers such as oil, gas, gas condensate and accompanying formation waters, located in the earth interior, contain many chemical elements, including natural radionuclides. The greatest danger to humans are natural radioactive substances from the families of radium and end radionuclides (uranium-238, thorium-232, and potassium-40 radionuclide). The removal of radioactive substances to the bottom surface occurs during the process of oil and gas production. Certain levels of radioactive contamination arise on the earth's surface and industrial equipment, depending on the amount and composition of radionuclides. Essentially, the radiation situation in places of contamination in terms of its parameters can be within the safe background or exceed it to levels dangerous to human health.

2.1. Method of preparing asphalt concrete mixture

Oil sludge is fed to heating up to 160 °C sand and crushed stone in the amount of 5%, 1 0% and15%. Then, non-flaxseed powder is introduced, after which the components are evenly distributed in the mixture. Preheated (at T = 140-160 °C) bitum is added to the resulting mixture, after which the blending is carried out within 60 minutes.
Since oil sludge contains 5.30% wt. mechanical impurities, when added to an asphalt concrete mixture, it can replace a small amount of sand.

The composition for the asphalt concrete mixture of grade I type B and the mixture to which oil sludge is added is presented in table 1.

Table 1. Composition of preparing asphalt concrete mixture.

Ingredient	Asphalt concrete grade I type B	With oil sludge addition, %		
		5	10	15
Crushed stone with a grain size of 0.5-2 cm, %	40	40	40	40
Sand, %	40	37,5	34	30

Screenings after crushing limestone, %	4	4	4	4
Non-activated microbe, %	8	8	8	8
Bitumen grade BND 70/100,%	8	5,5	4	3
Oil sludge, %	-	5	10	15

3 Results

The "Progress" spectrometric complex was used to study oil sludge for the presence of radioactive elements. Test conditions: temperature: 22.0 °C, humidity 52%. The results of oil sludge analyzes for the presence of radioactive elements are presented in table 2.

Table 2. Content of radioactive elements in oil sludge of Zhaik Munay LLP.

Name of indicators	Regulatory documents for test methods	Content	State standard No. 30108-94
Radium – 226 Bq/kg	MVI KZ 07.00.00304-2019	11,5	10-64
Thorium – 232, Bq/kg		< LDL*	56-81
Potassium – 40, Bq/kg		78,0	60-278
Cesium – 137, Bq/kg		0,6078	0,4-28
Strontium – 90, Bq/kg		49,0	17-128

LDL* - lower detection limit

As can be seen from the table, the content of radioactive elements in the oil sludge of Zhaik Munay LLP does not exceed the maximum permissible concentrations.

To study the composition of oil sludge, IR spectral analysis was carried out (Fig. 1).

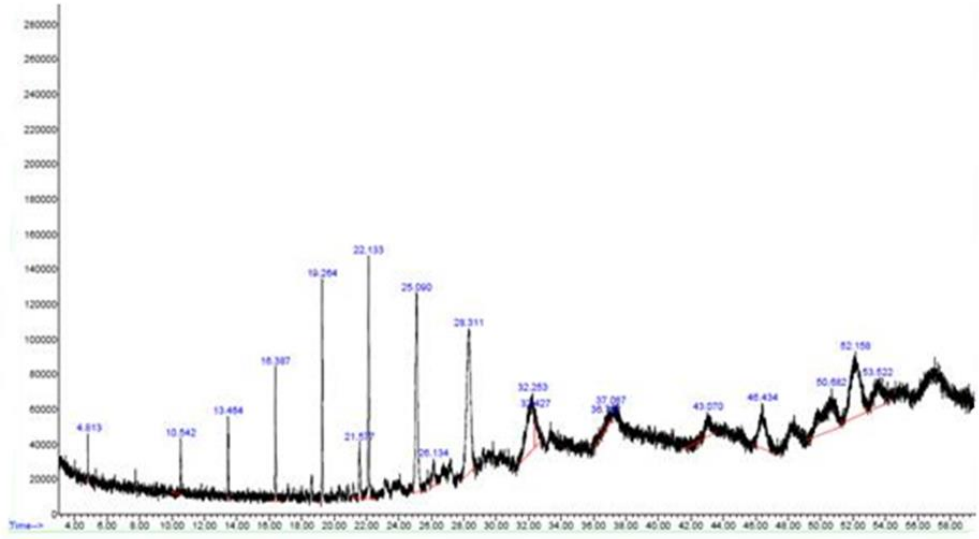

Fig. 1. IR spectral analysis of oil sludge from Zhayyk Munay LLP.

As can be seen from Fig. 1 presence of absorption lines 1600-1699 cm-1, include paraffins, polycyclic aromatic hydrocarbons, resins and asphaltenes. Their results

characterize the C=O carbonyl acid groups contained in aromatic acids. Consequently, this oil sludge can be used to produce asphalt bitumen and high-quality binders.

Physical properties of oil have been studied: density, funnel viscosity, content of oil products, water, and mechanical impurities. The results of the experiments are given in table 3.

Table 3. Physico-chemical properties of oil from Zhaik Munay LLP.

Parameters	Value
Density at 20°C, g/cm^3	0,8164
Viscosity (funnelя) at 80°C, Pa·s	2,11
Content of oil products, % wt.	34,50
Content of water , % wt.	4,00
Content of mechanical impurities, % wt.	5,30

As can be seen from table. 3, the viscosity is 2.11, and the content of oil products was 34.50%, which allows us to conclude that the studied oil sludge can be used as an additive to the asphalt concrete mixture.

The physiziko-mekhanicheproperties of asphaaltobeongrade I type B have been studied using oil sludge from 5 to 15%. The results of the analyzes are presented in Table 4.

Table 4. Fiziko-mehanicheskie properties andsfaaltobetoonwith the addition of oil sludge.

Name of indicators	Oil sludge, %			Asphalt concrete (grade I type B)	State standard No. 9128-2013
	5	10	15		
Ultimate compressive strength at a temperature of 50°C, MPa	0,69	0,74	0,71	0,67	not less than 0.7
Water resistance, % by volume	0,71	0,75	0,76	0,73	not less than 0.7
Water saturation, % by volume	5,12	4,95	4,99	5,23	over 4.0 up to 10.0
Shear stability according to internal friction coefficient, mm/min	0,84	0,89	0,86	0,87	not less than 0.80

Figure 2 shows the change in compressive strength and water saturation depending on the % content of oil sludge. The results of the analyzes are shown in the figure.

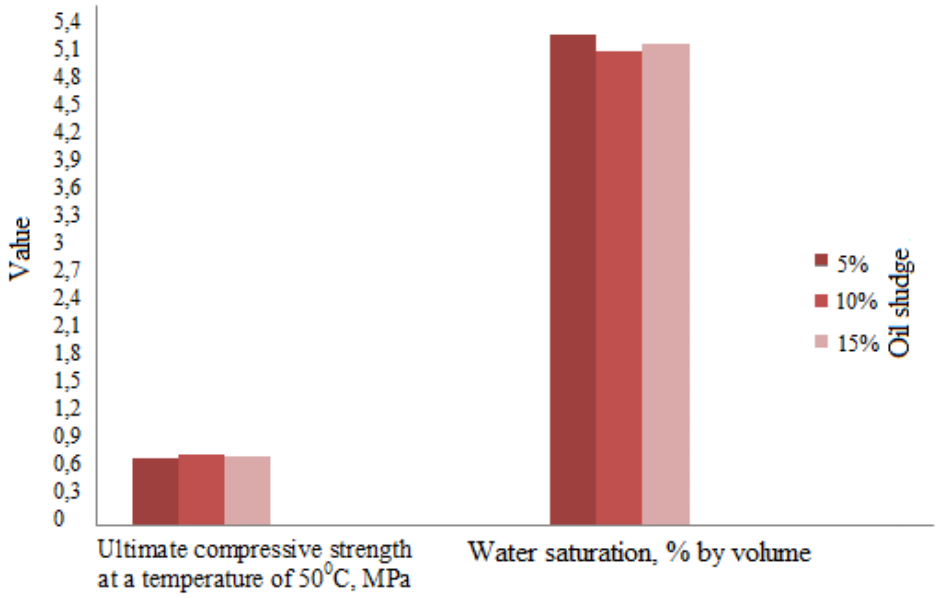

Fig. 2. Physical and mechanical properties of asphalt concrete using oil slidge from Zhaik Munay LLP.

As can be seen from table. 4 and fig. 2, when adding 5% oil sludge, the physical and mechanical properties of asphalt concrete are lower than when using 10%. The use of 15% oil as an additive leads to a deterioration in some of asphalt concrete properties: the strength limit decreases slightly with compression, and the stability of the structure shifts less according to the internal efficiency coefficient friction. The research carried out on physical and mechanical properties of asphalt concrete after adding oil sludge to the asphalt concrete mixture indicate that It is optimal to add 10% oil sludge, because at the same time, the compressive strength increases by 0.07% by volume. The higher this value, the less likely it is that asphalt concrete will be subject to destruction. After adding oil sludge to the asphalt concrete mixture, water resistance increases slightly (by 0.02%), and water saturation decreases from 5.12 to 4.95% by volume. With high water saturation, asphalt concrete becomes waterlogged, resulting in the material destruction during the cold period of the year due to repeated freezing and thawing. It follows from this that increased water saturation of asphalt concrete has a negative impact on its quality.

Previous studies by also showed that the use of oil sludge in road construction is advisable because allows you to preserve natural resources, reduce the cost of construction, reconstruction and major repairs of highways and reduce the environmental load in the regions [19].

Thus, as a result of the research, it was determined that the use of oil sludge as an additive to the asphalt concrete mixture allows saving oil bitumen, which is a valuable natural resource. When producing 1 ton of asphalt concrete, about 30 kg of petroleum bitumen is saved.

4 Conclusion

The possibility of using oil waste as an additive to building materials was researched. The properties of asphalt concrete before and after adding oil sludge were determined. It has been determined that the partial use of oil sludge as an organic binder in an amount of 10%

improves the properties of asphalt concrete: compressive strength increases, water resistance increases slightly, and water saturation, which characterizes its ability to fill with moisture all voids (pores, cracks) contained in the material, decreases. In addition to solving the problem of oil sludge disposal at oil industry facilities, the use of oil sludge as an additive in asphalt concrete allows saving an expensive product - oil bitumen, which will help reduce the cost of asphalt concrete mixture. The proposed technology allows you to save about 30 kg of petroleum bitumen in the production of 1 ton of asphalt concrete.

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