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The effect of sapropel additives on the properties of cement concrete for road construction

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In order to improve the quality of roads it is advisable to build foundations and pavements of cement concrete. It requires a considerable amount of cement-concrete mixtures and, consequently, cement. One way to increase the production volume of cement-concrete mixtures and cement is to use inert additives. The choice of inert additives can reduce the cost of cement and cement-concrete mixtures without compromising the properties of the cement concrete. In particular, sapropel can serve as an additive. The article proposes to conduct scientific research and obtain recommendations for the use of sapropel in the production of cement-concrete mixtures for road construction.

Key words: automobile road, cement concrete, inert additive, sapropel

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НАУЧНАЯ СТАТЬЯ
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Влияние добавки сапропеля на свойства цементобетона для дорожного строительства

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Для повышения качества автомобильных дорог целесообразно строительство оснований и покрытий из цементобетона. Для этого требуется значительное количество цементобетонных смесей и, соответственно, цемента. Одним из способов увеличения объемов производства цементобетонных смесей и цемента является применение инертных добавок. Выбор инертных добавок может снизить стоимость цемента и цементобетонных смесей без ухудшения свойств цементобетона. Такой добавкой, в частности, может служить сапропель. Предлагается проведение научных исследований и получение рекомендаций по использованию сапропеля в производстве цементобетонных смесей для дорожного строительства.

Ключевые слова: автомобильная дорога, цементобетон, инертная добавка, сапропель

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INTRODUCTION

Road construction and reconstruction work is actively conducted in Russia. New GOSTs have been adopted for quality construction, which should ensure the inter-repair normative terms for overhaul and repair of roads of technical categories I-IV not less than 24 years and 10 years, respectively (Russian Government Resolution No. 658 of 30.05.2017, Annex 4). For this purpose different repair and overhaul technologies can be applied: injection method, hot and cold regeneration, surface treatment, etc. The use of grouted concrete foundations and pavements is one of the most feasible solutions for the construction and reconstruction of highways, which ensures an increase in the time between repairs, structural quality, and durability [1].

Increasing the production volumes of cement-concrete mixtures for road construction will require an increase of cement demand. Cement is the most expensive component in the production of mixtures. To reduce its cost it is possible to use mineral additives (GOST 30515-2013), which can be active (AMA) and inert (IMA). The use of active additives can reduce cement consumption when preparing cement concrete mixture and change its properties (curing time, compressive strength). The use of inert additives also reduces the consumption of cement, but does not affect the strength of the cement concrete product. Curing times tend to increase in this case.

A difference is made between manufactured mineral additives (crushed slag, fly ash, micro-silica, burnt slate) and natural mineral additives (ash, tuff, volcanic slag, zeolite).

A number of researchers suggest using sapropel, clayey rocks, and fly ash as raw materials for the production of IMAs [2-5].

The formation of sapropel sediments takes place over a long period of time and is characterized by a number of catchment-specific features. High-ash clay and sandy sapropels are formed in water bodies characterizing by a low proportion of dissolved nutrients in water, which determines the absence of favorable conditions for the deposition of organic compounds on the bottom (characteristic for deep water bodies).

Algal-clay and algal-lime sapropels are usually formed in nutrient-rich bodies of water in the presence of benthic plants, which, dying off, create conditions for the formation of these sapropels. The same types of sapropels may form in well-warmed basins, rich with bottom vegetation and plankton. Algae-lime sapropels are formed in the presence of similar conditions and feeding by carbonate waters.

The sapropel sediments include both organic and mineral part. The organic part is formed by the flora and fauna of the water bodies and the mineral part by surface runoff from the watershed area. In addition, the accumulation of mineral matter occurs as a result of the life activity of aquatic organisms. Thus, sapropel, along with organic matter, is enriched with calcium, phosphorus, iron, trace elements and physiologically active substances as a result of physical, chemical, and biological processes.

According to GOST 25100-2020 (Soils, classification. - Moscow: Standartinform, 2020. 41 p.), «sapropel is an organomineral or organic sediment of freshwater stagnant water bodies (or buried sediment) with more than 10% mass of organic matter, of flowing or liquid consistency».

Studying the possibility of using sapropel for road construction is an urgent task for the Yaroslavl region, as there is a unique Lake Nero in the region, with sapropel reserves of over 250 million m^3.

According to the content and composition of organic and mineral matter, the lake sapropel deposits are divided into four types: clayey, algal-iron, algal-limestone, and calcareous.

It is possible to use low organic content sapropels - clayey, algal-limestone and calcareous - for the production of IMA from Lake Nero sapropel.

EXPERIMENTAL PART

Considering the fact that not all the sapropels of Lake Nero are suitable for use in agriculture as fertilisers or soil ameliorants, it is advisable to conduct further research to expand the areas of its application.

Road construction can be one of the important directions of sapropel application. Taking into account the studies on the use of sapropel in the production of cement-concrete mixtures in the Omsk region [7, 8], we decided to conduct research on the use of sapropel from Lake Nero in the Yaroslavl region for the production of cement-concrete mixtures and cement-sand mortars.

Samples were made using activated sapropel during testing. Activation of sapropel was conducted by roasting in laboratory furnace SNOL 1.6.2.5.1/11-M1 with subsequent grinding and sifting through sieves with square cells. The cement-concrete mixture was designed according to the methodical recommendations of Rosavtodor (Methodical recommendations on the selection of cement-concrete compositions for road construction in different climatic zones and taking into account the operating conditions of road surfaces / FDA Rosavtodor. – M., 2017. 81 p.).

The research was conducted at the road laboratory of Yaroslavl State Technical University. Limestone sapropel of Nero Lake, Yaroslavl region was used as a solid material. The compressive strength of 10x10x10 cm samples was determined after moulding and curing for 28 days. Table 1 (for cement concrete specimens) and Table 2 (for cement-sand mixture specimens) present the test results.

Table 1. Results of laboratory tests to determine the strength of ready-mixed concrete samples
Таблица 1. Результаты лабораторных испытаний по определению прочности образцов из товарного бетона

Sample number	Mineral content of sapropel in binder, %	Compressive strength, kg/cm^2	Average compressive strength, kg·cm^{-2}	Ratio of compressive strength for test samples to control samples
1.1	2.5	170	161	1.40
1.2	2.5	152		
2.1	5.0	167	167	1.28
2.2	5.0	167		
3.1	10.0	135	143	1.10
3.2	10.0	151		
4.1	15.0	130	132	1.01
4.2	15.0	134		
5.1	20.0	124	124	0.95
5.2	20.0	123		
6.1	Monitoring without sapropel	124	130	–
6.2		136		

Table 2. The results of laboratory studies to determine the strength of samples from commercial cement-sand mortar
Таблица 2. Результаты лабораторных исследований по определению прочности образцов из товарного цементно-песчаного раствора

Sample number	Mineral content of sapropel in binder, %	Compressive strength, kg/cm^2	Average compressive strength, kg·cm^{-2}	Ratio of compressive strength for test samples to control samples
1.1	2.5	25	31.7	0.54
1.2	2.5	15		
1.3	2.5	55		
2.1	5.0	85	65.0	1.11
2.2	5.0	25		
2.3	5.0	85		
3.1	10.0	105	98.3	1.68

Sample number	Mineral content of sapropel in binder, %	Compressive strength, kg/cm^2	Average compressive strength, kg·cm^{-2}	Ratio of compressive strength for test samples to control samples
3.2	10.0	100		
3.3	10.0	90		
4.1	15.0	100	85.0	1.45
4.2	15.0	65		
4.3	15.0	90		
5.1	Monitoring without sapropel	75	58.3	–
5.2		50		
5.3		50		

After the tests, the strength properties of samples made of cement-concrete mixtures and cement-sand mortars were compared.

RESULTS AND DISCUSSION

The data obtained by laboratory studies show an increase in the strength characteristics of samples made from experimental cement concrete mixtures and cement-sand mortars. The analysis of the results of investigations to determine the strength of experimental samples showed that the addition to cement-concrete mixtures IMA from sapropel Lake Nero increases the strength of cement-concrete. The most rational amount of sapropel IMA was 5%. The strength of the samples compared to the control samples is increased by up to 28% with this amount of IMA. The use of sapropel IMA for the production of commercial cement-sand mortar also leads to an increase in the strength of the samples. The rationally chosen quantity of IMA is 10%. The strength of the control samples increased by 68% (compared to the control samples without IMA) with the specified amount of IMA. According to the colloid-chemical hypothesis, the hardening of Portland cement is due to the formation of a gel-like component of calcium hydrosilicates, which occurs due to the addition of water to the original substance without its dissolution. The gel-like constituent glues the binder and aggregate particles together. The hydration of the underlying layers of the cement grains takes place over time and by sucking the water out of the gel, it causes the gel to harden and consolidate [9].

The increased strength can be explained by the accelerated hydration of the three-calcium silicate (alite) of the cement when limestone sapropel ash from Lake Nero is added to the cement in the early period of hardening (up to 3 months) [10].

CONCLUSIONS

The construction of cement-concrete foundations and pavements is directly related to cement requirements. Indeed, it is important to find a profitable cement-concrete composition without loss of quality. The solution is achieved by using inert mineral additives based on calcareous sapropel ash from freshwater reservoirs.

Sapropel reserves in Russia exceed 5 billion tonnes. The use of high ash sapropel deposits in construction will not only reduce the cost of cement concrete mixes, but also protect water bodies of bottom sediments and restore their ecological balance. As sapropel always has a different chemical composition, separate tests are required for each of their deposits.

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