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Features of the production of cement asphalt concrete using fuel ash

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Abstract. In this work, the objects of research are cement asphalt concrete obtained on the basis of cement binder and bitumen emulsion, using as mineral additives, waste from thermal power plants, in the form of fuel ash of various types. The analysis of foreign and domestic literature on this topic is carried out. In order to reduce the amount of inorganic binder (cement) consumed, as well as modification of organic binder (bitumen emulsion), fuel ashes of two domestic producers, ashes of CHP-2 and CHP-3 of Pavlodar based on Ekibastuz coals, were studied in the work. The influence of fuel ash on the properties of binders used in the work, as well as the properties of cement asphalt concrete compositions based on binders using fuel ash, has been established. The features of the production of cement asphalt concrete using fuel ash are described. The results of testing cement asphalt concrete without the use and with the use of fuel ash are presented.

Keywords: cement asphalt, plants, ash, waste, industry, building materials.

1. Introduction

The Republic of Kazakhstan speaks of the need to develop a environmentally friendly economy and closed production cycles, which implies "constant management of the material cycle in production and consumption, excluding the formation of waste that accumulates in the environment." It still contains a huge amount of ash and slag. Waste from thermal power plants and metallurgical waste at old landfills, which, unfortunately, continue to accumulate every year, which requires the development of new initiatives to implicate them in recycling [1].

Due to the high cost of road construction materials, the issues of using new technologies, efficient and unconventional materials, waste and by-products of industry in road construction are of particular importance. First of all, this applies to such technologies and materials that could improve the quality of asphalt concrete coatings, reduce the consumption of expensive binders of petroleum origin. The technologies under consideration also provide opportunities for the use of high-tonnage waste and industrial by-products as part of asphalt concrete mixtures.

The issues of the use of high-tonnage waste and by-products of industry are also important because they allow simultaneously solving the problem of the environmental plan - to free up vast territories of land occupied by waste, to prevent environmental pollution [2].

Studies were conducted to evaluate the ability of nanoparticles to reduce the temperature sensitivity of the mechanical properties of cement-asphalt mortar and to study the mechanism of the influence of nanoparticles on thermal characteristics. First, bending and compression tests of cement-asphalt mortar with nano-SiO_2 and nano-TiO_2 were carried out at five various temperatures varying from -20 °C to 60 °C, and the bending and compressive strength were measured. Based on the experimental results, the type, number of nanoparticles and the effect of temperature sensitivity on flexural and compressive strength were studied. In addition, changes in the composition and microstructure of cement-asphalt mortar were studied using a scanning electron microscope, and the temperature-related behavior of cement-asphalt mortar is explained on the basis of experimental observations [3].

Asphalt-Portland cement concrete has the properties of both flexible and rigid concrete. A laboratory study was conducted to evaluate the effectiveness of asphalt-Portland cement concrete composite under controlled conditions. The program included the following tests: stability, indirect tensile strength, compressive strength, modulus of elasticity, sensitivity to water, freezing and thawing, as well as resistance to chloride penetration [4]. The tests were carried out at three levels of wet curing: no wet curing, one-day wet curing and three-day wet curing. The samples were tested for 28 days. The results were compared with the results of control samples of hot-mix asphalt concrete and Portland cement concrete. The study concluded that the strength and durability properties of asphalt-Portland cement concrete composite are better than those of asphalt with a hot mixture. It was found that the penetration of chloride into the samples is less than in ordinary Portland cement concrete. The study shows that asphalt-Portland cement concrete composite is an effective alternative material for use as a bridge flooring coating [5].

The effect of cement kiln dust as a filler on the low-temperature characteristics of hot mix asphalt concrete was investigated. A laboratory program consisting of an assessment of the durability of asphalt concrete of a hot mixture in freeze-thaw cycles using indirect tensile strength testing and analysis of fatigue behavior at four temperatures of 20, 0, -10 and -20 °C using a four-point bending fatigue test. In addition, an environmental assessment was carried out with respect to the presence of heavy metals in the dust compounds of the cement kiln by applying a leaching toxicity test. According to the results obtained, mixtures containing cement kiln dust filler demonstrated better resistance to freeze-thaw cycles compared to the control mixture containing limestone. In addition, mixtures containing cement kiln dust showed a higher fatigue life compared to the control mixture, and for all mixtures, fatigue life decreased due to a decrease in temperature [6]. However, at lower strain levels of 150 micro-stresses, the fatigue life of the studied mixtures was largely similar, and even higher fatigue life was obtained by reducing the test temperature. In addition, the results of the toxicity test by leaching showed that the number of heavy metals in the filtrate from asphalt concrete hot mixture containing cement kiln dust was low and met the required criteria [7].

The composition of cement-asphalt concrete mixture is characterized in the invention. Technical result: reduction of the amount of complex binder while improving the physical and mechanical properties of the resulting material: increased water resistance and long-term water resistance, resistance to alternate freezing and thawing, increased modulus of deformation and strength [8].

The purpose of the experimental investigations was to obtain a hollow wall stone based on ash and slag waste with a strength not inferior to products made according to a usual recipe. A study was carried out with selected samples of bauxite sludge from the sludge dumps of the Pavlodar Aluminum Plant, as fillers was used metallurgical slag of fractions 0-5 and 20-30 according to 6 recipes made in forms 100x100x100 mm. The resulting samples with various ratios of components in the mixture were examined for compressive strength, moisture absorption, and frost resistance. It has been established that when ash and slag waste is added to the concrete mixture in an amount of up to 35 % by weight of dry components, the strength characteristics of the hollow wall stone correspond to the selected brand [9].

2. Methods and Materials

Studies of raw materials, binders using mineral additives, as well as compositions of final composites were carried out using the material and scientific and technical base of the NAO "Toraigyrov University".

When evaluating the combustion products of coal in a hot asphalt-concrete mixture, it was found that the combustion products of fine coal are a by-product of coal combustion in the production of electricity. Fly ash is commonly used in Portland cement concrete. However, some fly ash was used in hot mix asphalt concrete as mineral fillers. Due to the current changes in environmental protection requirements for emissions, large volumes of fly ash containing sulfur cannot be used in traditional concrete. Therefore, this study was undertaken in order to find out whether some of the smaller evils could be usefully used in hot mix asphalt concrete. In this project, fly ash was mixed with asphalt binder PG 58 - 28 in various percentages (5 %, 10 % and 15 %). A rotational viscosity test was carried out on the mixture to determine what percentage of fly ash by weight of asphalt binder would be acceptable. All percentages were deemed viable [10].

Then Hamburg tests were carried out tracking these mixtures of asphalt concrete hot mix. The stages of sample preparation included: drying of aggregates to a constant weight, dosing of aggregates, heating of aggregates and binder to the mixing temperature, mixing of binder and aggregates, conditioning (short-term aging) and compaction of the sample to the appropriate percentage of voids using the gravity machine "Superave" compactor. The process of mixing asphalt concrete with a hot mixture is shown in Figure 1.

a)

b)

c)

d)

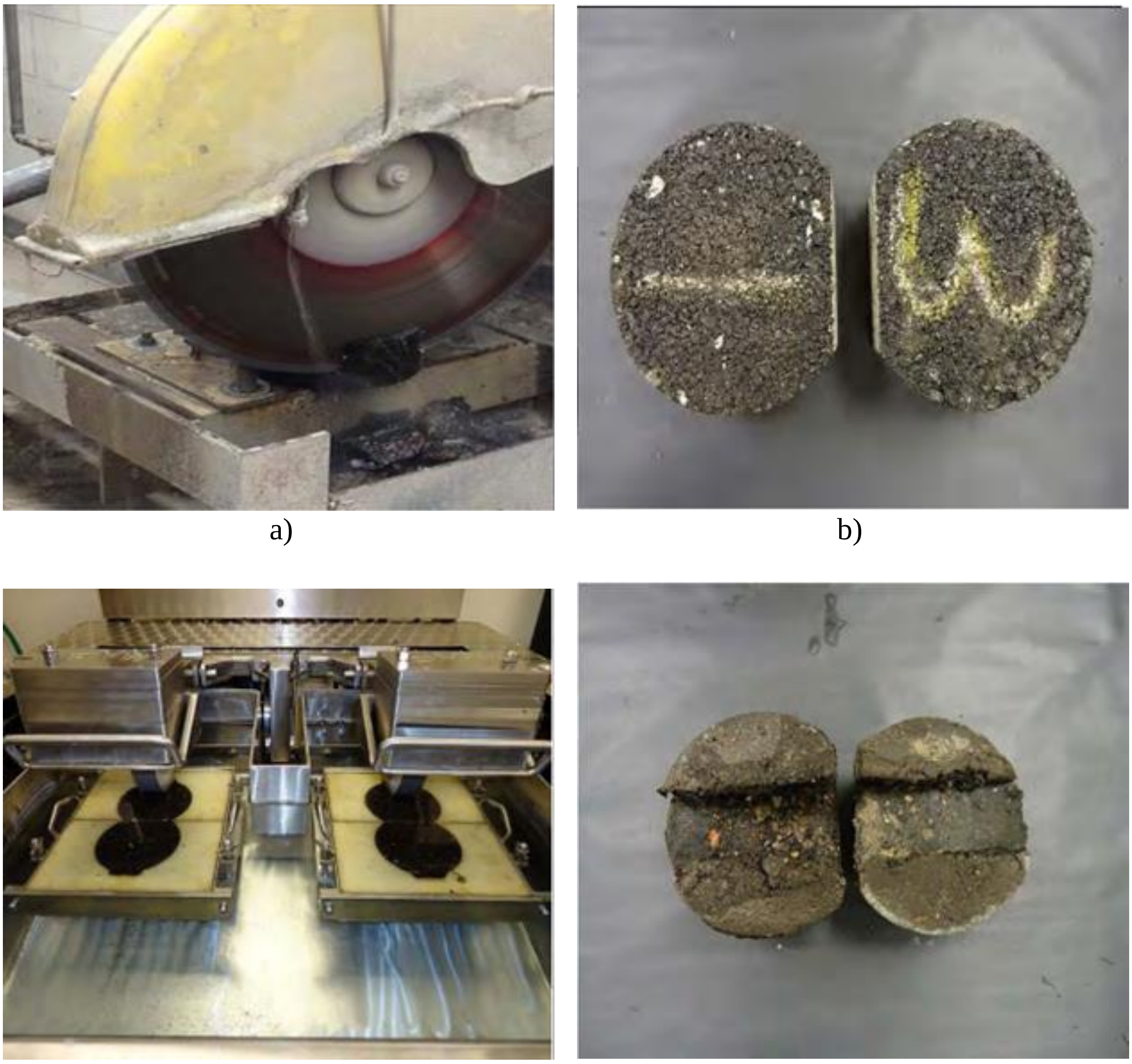
Figure 1 – The process of mixing asphalt concrete with a hot mixture: a) Heating aggregate to mixing temperature; b) Adding asphalt to the aggregate in the mixer; c) Mixing of asphalt and aggregate in the mixer; d) Mixture kept at compaction temperature for 2 h.

The compaction of the sample using the gravity machine "Superave" compactor is shown in Figure 2.

a) b) c)

Figure 2 – Compaction of the sample using a gravity machine "Superave": a) Pine Superpave Gyratory compactor; b) Pouring HMA into SGC mold; c) Extruding the sample from the mold

The stages of the Hamburg test are shown in Figure 3.



a) b)

c) d)

Figure 3 – Testing stages: a) Sample is cut along the edge of the mold; b) Vertical-cut sample; c) Spicements placed in molds and mounted in tray; d) Failed sample (rut depth >20 mm)

Based on the results of the Hamburg test, the most effective mixture with 15% fly ash was selected for further tests, such as modified Lottman, dynamic module and S-VECD test, and comparison with the control group (without fly ash). The results showed positive dynamics [11].

Features of the production of cement asphalt concrete using fuel ash. Taking into account the formation of an optimal structure, as well as for effective quality control of both raw materials and cooking technology, one of the most rational methods was used in the work – separate and sequential mixing. This technology consists in separate preparation of cement-ash-sand mortar with fine aggregate (sand) and black crushed stone (crushed stone treated with an emulsion using ash), after which they are supposed to be mixed together. Figure 4 shows a scheme for obtaining cement asphalt concrete.

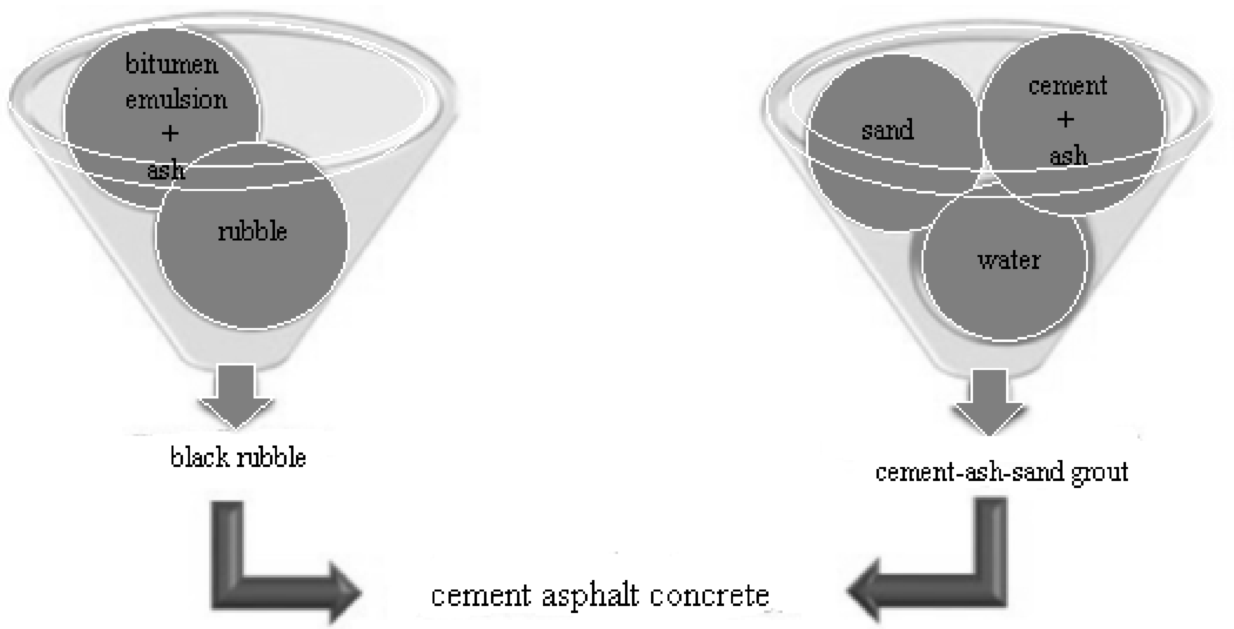


Figure 4 – Scheme for obtaining cement asphalt concrete

Separate mixing of crushed stone with bitumen emulsion, in this case modified with mineral additives in the form of fuel ash, allows you to regulate the distribution of bitumen over the surface of crushed stone (reducing the area of coating of crushed stone grains with bitumen by about a third, up to 60-70%), ensuring its contact directly with cement stone. The distribution of bitumen over the crushed stone surface is shown in Figure 5.

Figure 5 – The surface area of crushed stone with bitumen as a result of the decomposition of bitumen emulsion: a) without additives; b) with ZSHO Pavlodar CHP-2; c) with ZSHO Pavlodar CHP-3

3. Results and Discussion

The average chemical composition of ash and slag waste of the surveyed CHP-2, CHP-3 of Pavlodar is shown in Table 1 [12].

Table 1 – Limits of the average content of the main components of the ash (ash and slag waste)

Component	Average content, %		Component	Average content, %	
	from - to	average		from - to	average
SiO_2	51–60	54,5	CaO	3,0–7,3	4,3
TiO_2	0,5–0,9	0,75	Na_2O	0,2–0,6	0,34
$Al2O_3$	16–22	19,4	K_2O	0,7–2,2 1	1,56
$Fe2O_3$	5–8	6,6	SO_3	0,09–0,2	0,14
MnO	0,1–0,3	0,14	P_2O_5	0,1–0,4	0,24
MgO	1,1–2,1	1,64	c.l.	5,8–18,8	10,6

The technological scheme of the plant for the production of cement asphalt concrete is shown in Figure 6.

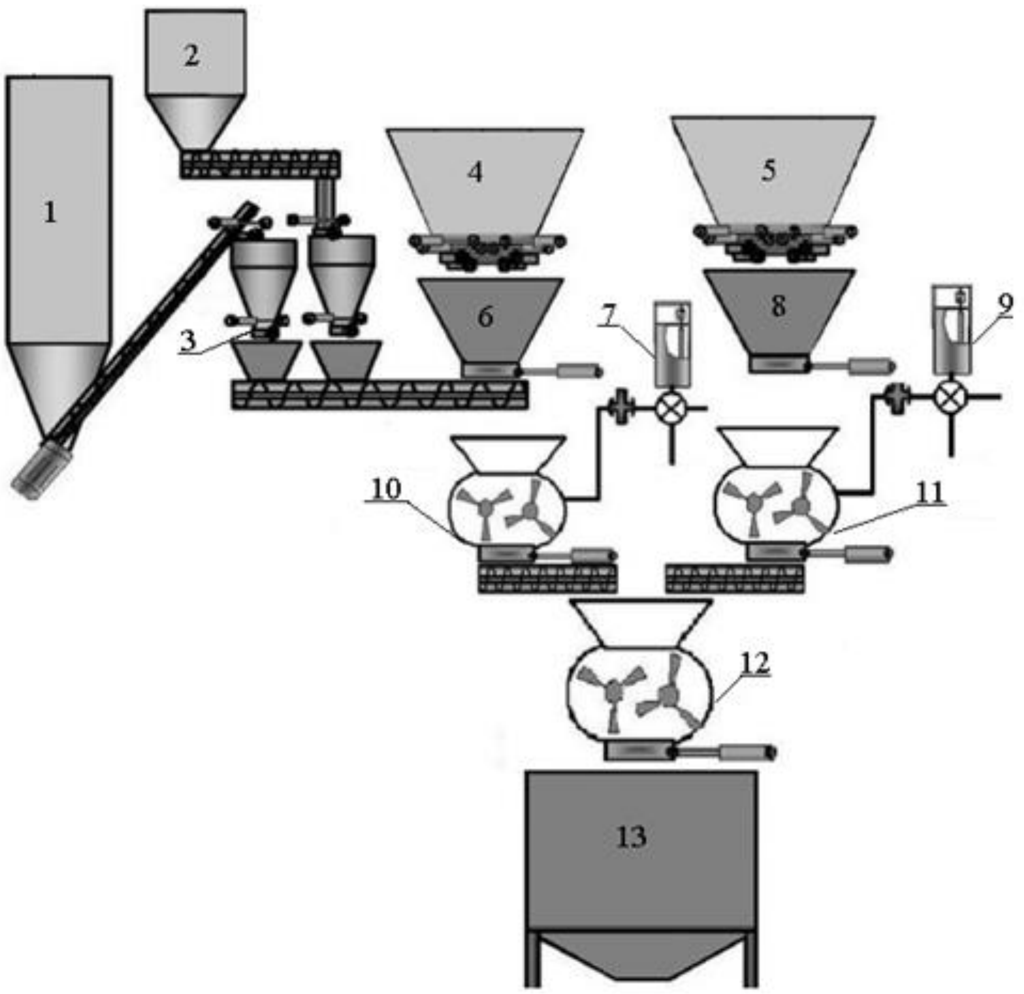


Figure 6 – Technological scheme of the plant for the production of cement asphalt concrete: 1 – cement warehouse; 2 – mineral additive warehouse; 3 – cement and additives dispenser; 4,5 – storage bins; 6 – sand dispenser; 7 – water dispenser; 8 – rubble dispenser; 9 – bitumen emulsion dispenser; 10 – mixer for cement-ash-sand mortar; 11 – mixer for black rubble; 12 – mixer for cement asphalt concrete mix; 13 – storage of cement asphalt concrete mixture

The technology of construction of structural layers of pavement made of cement asphalt concrete includes the following main stages:

Stage 1. Preparation of cement-asphalt concrete mixture at an asphalt concrete plant using stationary mixers of forced mixing.

Stage 2. Transportation of the organomineral mixture by dump trucks directly to the installation site. Taking into account the features of the resulting mixture (the presence of a hydration type of hardening binder closed with water with limited setting times), the maximum transportation time does not exceed 30 minutes at an ambient temperature of 20-30 °C and 1 hour at a temperature below 20 °C.

Stage 3. Distribution of semi-rigid composite material using an asphalt paver of any type.

Stage 4. Compaction of cement asphalt concrete mixture. The resulting material is compacted using the technology of rolled concrete.

4. Conclusions

As a result of the analysis of domestic and foreign literature, the possibility and expediency of using fine mineral materials of various natures as part of emulsion systems for their stabilization has been established, and the main criteria for mineral materials have been identified. One of the promising types of mineral raw materials for the modification of bitumen emulsions are fuel ash, however, due to the lack of experimental data, determining the effectiveness and expediency of their use is one of the most important tasks. This will expand the range of modifying additives to stabilize emulsion systems and increase the use of fuel ash.

It is advisable to consider in the direction of expanding the mineral resource base of modifying additives for the production of cement asphalt concrete, as well as analyzing the physical and mechanical characteristics and structural transformations of the structural layers of pavement made of cement asphalt concrete during operation

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