Technobius, 2024, 4(2), 0056, DOI: https://doi.org/10.54355/tbus/4.2.2024.0056

Technobius

https://technobius.kz/

e-ISSN 2789-7338

Article

Mineral powder based on basalt insulation waste for asphalt concrete

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Abstract. The article discusses the composition and production technology of mineral powder using waste basalt insulation. This study aims to confirm the hypothesis about the possibility of using basalt waste in the production of mineral powder with technical parameters corresponding to approved standards for the production of asphalt concrete. For definition of qualitative indicators of the received product in comparison with the control sample the researches of the basic indicators of mineral powder according to operating norms are given. Such indicators as grain composition of mineral powder, porosity and density were determined, indicating a more dense structure of the developed composition: the content of particles finer than 0.125 mm – 91.4 %, finer than 0.063 mm – 82.2 % with porosity index 28.1 % and true density 2.49 g/cm^3. It was found that the mineral powder from waste basalt mineral slabs has a uniform and balanced grain distribution. At moisture content of samples less than 0.1 % by weight the bitumen capacity index of the tested mineral powder sample in comparison with the control sample showed better value by 2 g, at the same time the degree of swelling of samples from the mixture of powder and bitumen showed better result by 0.1 %. The obtained results indicate that the mineral powder on the basis of waste is able to hold bitumen well on its surface, which contributes to the improvement of adhesion between bitumen and mineral particles. The lower degree of swelling characterizes the increased water resistance and frost resistance of asphalt concrete with the use of this mineral powder. Considering that basalt mineral slabs are waste, their use in the production of mineral powder for asphalt concrete fits into the concept of sustainable construction and can contribute to waste reduction and environmental sustainability of the construction process.
Keywords: mineral powder, waste utilization, resource conservation, property testing, asphalt concrete.

1. Introduction

According to statistical studies on waste disposal by industrial enterprises, about 13000 tons of waste of basalt fiber-based thermal insulation materials and 4350 tons of waste of basalt fiber and materials based on it are generated annually in Kazakhstan [1]. Despite the fact that mineral wool waste accounts for only a small share of total construction waste by mass, it requires large capacities for transportation and disposal due to its low bulk density, and its utilization remains low compared to other types of waste. A study on the utilization of direct waste basalt rock wool produced during the manufacturing process is more suitable for subsequent use due to their high degree of purity than the products after processing [2]. Due to their high content of chemically inert compounds such as silicon dioxide, calcium oxide and aluminum oxide that improve fire retardant properties, mineral wool wastes can be used as fillers in composite materials for construction [3]. In addition, given their potential to absorb petroleum products, mineral wool waste can also be used as an absorbent. We suggest the possibility of solving the problem of environmental protection in the utilization of basalt board production wastes by processing them into mineral powder. The purpose of the study is to determine the compliance of the technical properties of mineral powder of the proposed composition with the regulatory requirements for mineral powders for asphalt concrete. The objective of the study is to develop a composition of mineral powder from industrial waste for the production of asphalt concrete with technical indicators that meet the approved standards.

In the pursuit of sustainable and green construction, the integration of recycled and waste materials has become the centerpiece of innovation [4–7]. One such pioneering development is the use of waste-derived mineral powder in the production of asphalt concrete. This revolutionary approach not only solves the environmental problems associated with waste management, but also improves the performance and sustainability of asphalt concrete, making it a win-win for both the construction industry and the environment.

Mineral powder from waste materials such as industrial by-products and mining waste provides a valuable alternative to traditional asphalt additives [8–10]. These include materials such as fly ash, slag and other mineral-rich wastes that can be finely ground to produce a high-quality powder suitable for asphalt concrete production. By recycling these materials, the construction industry contributes to reducing the environmental burden associated with waste disposal [11–13].

The inclusion of waste mineral powder significantly improves the performance of asphalt concrete. These waste fillers improve the cohesion and adhesion properties of the asphalt binder, resulting in a more stable and durable pavement structure. The unique composition of the mineral powders can help improve resistance to rutting, cracking and moisture, resulting in longer asphalt pavement life. The technology of mineral powder production implies obtaining an effective additive in asphalt concrete pavement, and is also considered as a way of utilization of basalt mineral insulators production waste, solving the problems of production waste. The composition presented in Table 1 was determined to obtain mineral powder based on basalt insulation waste [14].

Table 1 – Composition of mineral powder based on basalt insulation waste per 0.5 m^3 [14]

Type of material	Waste mineral insulation (wool), kg	Water, liters	NaOH, kg	Fuzz, kg	H_2SO_4, kg
Mineral powder based on waste from basalt insulation materials production	1000	1000	15	30	200

In the production of mineral powder, it is necessary to soak mineral insulation waste with water, temperature not lower than 18 °C. The hydrophobizer is prepared separately: the fuzz is combined with NaOH alkali, the temperature of combination is not lower than 22 °C, and is passed through the RPA (rotary pulsation apparatus), forming a water-soluble emulsion. After the obtained mixture is combined with H_2SO_4 acid and mixed thoroughly, then the obtained mixture is placed in a drying chamber and then in a grinding mill. The obtained powder is sieved and packed.

Figure 1 presents technological scheme of mineral powder production for asphalt concrete.

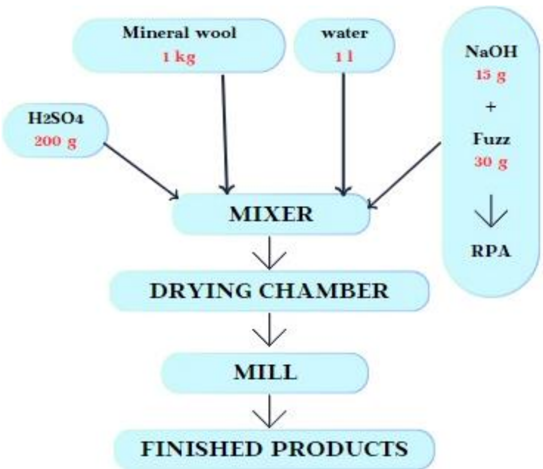

Figure 1 – Scheme for production of mineral powder for asphalt concrete [14]

2. Methods

Studies of the obtained mineral powder on the basis of wastes were carried out in accordance with the current regulations. Mineral powder for asphalt concrete of Temirtau deposit was taken as a control sample. The tests were conducted at the road specialized laboratory of the National Center for the Quality of Road Assets.

2.1 Determination of grain composition

The results of the study of the grain composition of the selected mineral powders will allow an objective assessment of the quality of the structure of the materials [15]. During the test, selected dried samples of mineral powders are poured with a small amount of water and rubbed for up to 2 minutes. The essence of the experiment is the distribution and separation of grains of mineral powder samples by sieving through sieves and determining the residues on each sieve (Figure 2).

Figure 2 – Washing mineral powder through a 0.063 mm sieve

Density and porosity studies were also conducted on the samples to further characterize the mineral powders according to the approved standards [16].

2.2 Determination of moisture content

Laboratory determination of mineral powder moisture content was carried out according to the norms of the national standard [17]. Determining the moisture content of mineral powder is an important quality control step, as moisture content affects its physical and mechanical properties and interaction with bitumen. Moisture is determined by drying the sample to a constant mass.

The essence of the method is to determine the moisture content in the powder (Figure 3).

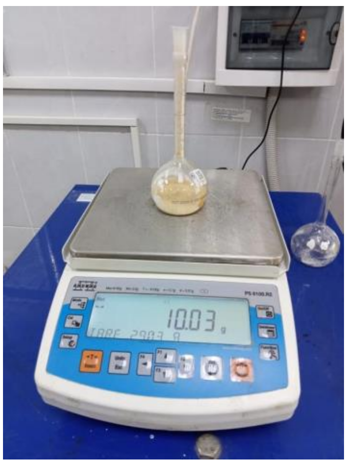

Figure 3 – Determination of sample weight after drying

A sample of mineral powder with a mass of about 100 g is taken. The exact mass is recorded before drying. The mineral powder sample is dried in a desiccator at 105-110 °C to a constant mass. After drying, the sample is placed in a desiccator to cool to room temperature. The mass of the dried sample is determined. The moisture content of the mineral powder is calculated as the ratio of the mass loss during drying to the initial mass and expressed as a percentage.

2.3 Determination of swelling of mineral powder samples with bitumen

The swelling of mineral powder samples with bitumen was determined to evaluate the interaction between mineral powder and bitumen in asphalt concrete. This parameter is important to prevent undesirable phenomena such as bitumen separation from the mineral aggregate.

The essence of the method is to determine the volume increment of samples with water saturation from 4 % to 5 % by volume from the mixture of powder with bitumen after saturation with water under vacuum conditions and subsequent incubation in hot water (Figure 4).

Figure 4 – Determination of swelling of the mixture with bitumen

The results of each test are evaluated to the first decimal place. The maximum permissible deviation between parallel measurements shall not exceed 0.2 %.

2.4 Determination of bitumen capacity

Tests were also conducted to determine the bituminous capacity of mineral powders to characterize their interaction with bitumen (Figure 5) in accordance with the approved methodology [18-19]. The bitumen capacity of mineral powder is determined to estimate the amount of bitumen required to completely envelop the powder particles.

Mineral powder weighing about 100 grams is dried to a constant mass at 105-110 °C. The cooled powder is placed in an desiccator to prevent absorption of moisture from the air. The bitumen is heated in a thermostat to a temperature of 160 °C. A small amount of the heated bitumen is added to the mineral powder and the mixture is thoroughly mixed until the bitumen is evenly distributed on the surface of the powder particles. The addition of bitumen is continued in batches until all the powder particles are completely covered with bitumen and the mixture has a homogeneous consistency. Bitumen capacity is defined as the ratio of the mass of added bitumen to the mass of mineral powder and is expressed as a percentage. To increase the reliability of the results, the test is repeated three times.

Figure 5 – Determination of bitumen capacity

3. Results and Discussion

This study examined the use of mineral powder obtained from waste basalt mineral slabs in the production of asphalt concrete. Our research focused on studying the effect of mineral filler on asphalt concrete properties: adhesion to bitumen, grain composition, environmental resistance and other important characteristics. Statistical methods of data processing were used to ensure the reliability of the results. The main results and conclusions obtained during the study are presented below.

3.1 Grain composition study

Let us consider the results of the study of grain composition of mineral powder obtained from waste basalt mineral slabs and its influence on the properties of asphalt concrete. The conducted analyses provide an in-depth look at the structure and quality of mineral filler in the context of its application in road pavement construction (Table 2).

Table 2 – Grain composition of studied mineral powders

Type of sample	Grain composition according to GOST, %, not less than			Porosity according to GOST, %, no more than	True density according to GOST, g/cm^3
	finer than 2.0 mm	finer than 0.125 mm	finer than 0.063 mm	35	not standardized
Control sample	100.0	94.2	78.1	29.0	2.45
Mineral powder based on waste from basalt insulation materials production	100.0	91.4	82.2	28.1	2.49

The obtained results showed a denser structure of mineral powder based on waste mineral insulation boards compared to the control sample, with a minimum content of dusty particles affecting the quality of asphalt concrete. The grain composition study showed that the mineral powder from basalt mineral board waste has a uniform and well-balanced grain distribution. This ensures stability and homogeneity of the internal structure of asphalt concrete.

3.2 Resistant to moisture and chemical influences

The test results showed that the mineral powder based on mineral board production waste has a higher capacity compared to the control sample due to the greater adhesion of bitumen to the surface of mineral particles. Table 3 shows the obtained values of the test results.

Table 3 – Test indicators of interaction with bitumen of mineral powder samples

Type of sample	Swelling of samples from the mixture of powder and bitumen according to GOST, % by volume, not more than	Bitumen capacity index according to GOST, g, not more than	Humidity according to GOST, % by weight, not more than
	2.5	65	1.0
Control sample	2.1	54	less than 0.1
Mineral powder based on waste from basalt insulation materials production	2.0	52	less than 0.1

The obtained value of bituminous capacity of mineral powder based on waste means that to cover a unit mass of mineral powder to the state of complete envelopment of particles it needs less bitumen, compared to the control sample. The high bitumen capacity means that the waste-based mineral powder is able to retain bitumen well on its surface, which helps to improve the bond between the bitumen and the mineral particles. This is important for the strength and durability of asphalt concrete. Knowing bitumen capacity helps to optimize the amount of bitumen in the mix, which helps to save material and improve the technological and performance characteristics of the asphalt concrete.

The degree of swelling of mineral powder characterizes its ability to absorb moisture and increase in volume when in contact with water. This indicator of the sample of mineral powder on the basis of waste is lower than the control one by 0.1%, which characterizes a higher water resistance of mineral powder. The high degree of swelling of mineral powder can increase porosity and reduce the frost resistance of asphalt concrete, which adversely affects the durability of the road surface.

The bituminous capacity index and the degree of swelling of mineral powder are important characteristics [20] that determine the quality and performance of asphalt concrete.

3.3 Environmental feasibility

The use of waste basalt mineral slabs in the production of mineral powder for asphalt concrete will not only improve the technical characteristics of the material, but also make a significant contribution to reducing waste and improving the environmental sustainability of the construction industry. In general, the results of our research emphasize the promising use of mineral powder from basalt mineral slab waste to improve the performance of asphalt concrete, as well as its positive impact on the environmental sustainability of the construction industry.

4. Conclusion

Advantages of using mineral powder from mineral insulation waste in asphalt concrete:

– increased stability and durability;

– the introduction of mineral powder derived from mineral insulation waste strengthens the asphalt mixture, improving its stability and overall durability;

– the unique composition of these mineral powders can improve critical asphalt properties, including resistance to rutting, cracking and moisture.

Processing of construction waste into mineral powder and its use in asphalt pavement is effective from the point of view of environmental protection and resource saving. Our proposed technology of mineral powder production on the basis of recycling of basalt insulators production wastes will allow to obtain high-quality road asphalt concrete with maximum Kazakhstani content and quality indicators in accordance with the standard norms.

The proposed technology of obtaining mineral powder on the basis of recycling of basalt insulation waste as a filler for asphalt concrete is considered for the first time and involves the production of material for road surfaces with an effective bond "binder-mineral filler" to stabilize the main qualitative indicators of asphalt concrete under the influence of temperatures.

Acknowledgement

This research was funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR21882278 «Establishment of a construction and technical engineering centre to provide a full cycle of accredited services to the construction, road-building sector of the Republic of Kazakhstan»).

The authors would like to express their gratitude to the research and production center «ENU-lab» in conducting laboratory tests of foam concrete.

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Assel Jexembayeva – resources, funding acquisition.
Beksultan Chugulyov – testing.

Conflict of Interest: The authors declare no conflict of interest.

Use of Artificial Intelligence (AI): The authors declare that AI was not used.

Received: 27.05.2024
Revised: 12.06.2024
Accepted: 13.06.2024
Published: 13.06.2024