The Ceramic Dust Utilization at the Asphalt Mix Production

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Abstract. The possibility of using industrial waste - ceramic dust in the production of asphalt concrete is considered. The characteristics of ceramic dust and building sand are compared. The analysis of the physicomechanical characteristics of the asphalt concrete mix is made. This mixture has a different content of ceramic dust (10\%, 30\%, 50\%) of the amount of building sand. The samples made from this mixture were tested in a certified building laboratory. It is shown that the use of ceramic dust in the composition of the asphalt concrete mixture as a filler does not significantly change either the structure or the physical and mechanical properties of the latter. The possibility of using in construction practice asphalt concrete with a 50\% replacement of sand with ceramic dust is proved.

1. Introduction
Recycling is one of the actual problems of the modern world. The term Recycling (waste recycling) means the return to circulation, reuse of materials and products. Recycling is not only economically viable, but also an environmentally preferable solution to the problem of waste utilization [1]. Its introduction has allowed many countries to achieve significant success in the processing of major types of waste by the mid-80s. It was at this time that the concept of using secondary resources became widespread abroad [2]. The policy of Russia in the field of waste management is also focused on reducing the amount of waste generated and on the development of methods for their maximum utilization [3].

The use of industrial wastes as fillers and mineral powders in the asphalt concrete production is promising. The use of such fillers can help to increase the heat, crack resistance and shear resistance of the road composite, as well as reduce the asphalt mix preparation cost and reduce environmental pressure on the environment [4-8]. One of the effective ways to use industrial waste in the asphalt concrete production is the use of slags [9-10], which solves several current problems simultaneously: it improves the environment protection conditions; increases work productivity and rational use of local raw materials. The use of industrial waste from the Krasnoyarsk Territory in the manufacture of road asphalt is discussed in [11]. It is shown that the tailings of neutralization can be used as a mineral powder, and granulated slags as a fine aggregate in the composition of road asphalt concrete. The foundry by-product is quartz sand coated with a thin film of burnt carbon. Also, waste generated in the process of coal mining in the form of coal dust is widely used in the production of road-building materials [12-16]. The possibility of using asbestos production wastes for road construction is
investigated in the articles [17-18]. Domestic and foreign experience in creating colored asphalt concrete using black metallurgical wastes was considered in [19]. The study of various mineral fillers used in bitumen mixtures was considered in [20]. Modified Blends containing marble dust as a filler were investigated in [21]. Comparative analysis of effects of filler materials on performance of asphalt presented in [22, 23].

For construction practice, the use of industrial waste - ceramic dust in the production of asphalt concrete, is of great interest. Ceramic dust is formed as a result of jet abrasive cleaning of metal surfaces at large metalworking plants and enterprises: crane, ship repair, auto repair, etc.

2. Materials and methods
This article explores the possibility of using ceramic dust as a filler for asphalt concrete mix. In this paper, we studied the possibility of using ceramic dust as filler for asphalt concrete mix. The purpose of the work is to estimate the physicomechanical characteristics of the asphalt mix with filler in the form of waste production - ceramic dust. Task setting includes testing of ceramic dust in laboratory conditions according to the methods of GOST 8735-88 "Sand for construction works. Test methods". Characteristics of ceramic dust and rationed in accordance with GOST 8736-93 "Sand for construction works. Technical conditions" characteristics of building sand are presented in table 1.

| Indicator | Ceramic dust indicator value | The requirements of GOST 8736-93 for fine sand class II |
|-----------|-----------------------------|--------------------------------------------------------|
| Size module | 1,96                         | from 1,5 to 2,0                                        |
| Grain content: Total residue on sieve No. 063 Less than 0.16 (mm) | 33,1 12,8 | from 10 to 30 (in percent by weight), no more than 20 |
| Dust content (% by weight) | 0,5 | (in percent by weight), no more than 5 |

The given characteristics of ceramic dust meet the standards for Class II sand. A slight excess of the total residue on sieve No. 063 is within acceptable limits (no more than 5%).

The selection of the asphalt mixture composition was made for the study. The mixture is the composition of fine-grained hot asphalt concrete mix Type B of grade II for dense asphalt concrete intended for the installation of the top layer of the pavement in the III road-climatic zone, including: crushed limestone fraction 5-20 mm (50% of the mixture); sand construction (15% of the mixture); crushed stone-sand mixture (35% of the mixture); bitumen oil grade BND90 / 130. Grain compositions of mineral materials are selected in accordance with the requirements of normative document GOST 9128-2009 "Road asphalt concrete, airfield and asphalt concrete mixtures". The content of bitumen in asphalt concrete is 6.2% by weight of the mineral part. This amount of bitumen is the average value recommended in GOST 9128-2009 for all road-climatic zones.

There were developed 4 asphalt concrete mixture compositions for the study: 1) standard mixture - a mixture that does not contain waste (pure mixture); 2), 3), 4) the asphalt concrete mixes, respectively, with content 10%, 30% and 50% of ceramic dust from the amount of construction sand that is part of the mixture. It was made on 15 cylindrical samples with a diameter of 71.4 mm and a height equal to the diameter for each type of mixture.

The tests were carried out in a certified laboratory of the State Administration of the Road Economy of the Omsk Region. All 60 samples of asphalt mixes were made and tested in accordance with GOST 12801-98 "Materials based on organic binders for road and airfield construction. Test methods". To justify the reliability of the results of experimental studies used the apparatus of mathematical statistics. All the results obtained are evaluated on a small sample using Student's distribution.

The quality of the asphalt mix was evaluated by the following indicators:
1) the average density of compacted material;
2) the average density of the mineral part (skeleton);
3) water saturation;
4) tensile strength of asphalt concrete at compression at temperatures of 50 °C and 20 °C;
5) shear stability characteristics;
6) water resistance.

The test results are shown in table 2.

| Table 2. Indicators of physico-mechanical characteristics of asphalt mixes. |
|-------------------------------------------------|
| Average density of compacted material, (g/cm³)  | 2,38 | 2,37 | 2,39 | 2,38 |
| Average density of the mineral part, (g/cm³)   | 2,24 | 2,23 | 2,25 | 2,24 |
| Water saturation, (%)                          | 2,7  | 1,7  | 2,2  | 3,7  |
| Compressive Strength at a temperature 50°C, (MPa) | 1,1  | 1,1  | 1,3  | 1,4  |
| Compressive Strength at a temperature 20 °C, (MPa) | 3,7  | 3,4  | 3,7  | 3,8  |
| Average work with uniaxial compression, (J)     | 26,7 | 24,2 | 33,1 | 26,7 |
| Medium compression work according to Marshall scheme, | 133,2 | 29,7 | 79,8 | 49,1 |
| Internal friction coefficient                   | 0,82 | 0,51 | 0,79 | 0,71 |
| Shear adhesion at temperature 50 °C, (MPa)      | 1,35 | 1,71 | 1,66 | 1,50 |
| Water resistance, (%)                           | 0,76 | 0,85 | 0,92 | 0,87 |

The arithmetic mean value of the results of determining the average density of three samples was taken as the average density of the compacted material. Analysis of the results showed that the use of ceramic dust in the composition of the asphalt mix does not change the structure of the latter and does not change the average density of the compacted material. The average density of the mineral part is calculated from the results of determining the average density of the compacted material.

The water saturation of the samples increases as the amount of ceramic dust in the asphalt mix increases, remaining within the limits (1.5 4%) established by GOST 9128-2009. It should be noted that the mixture with 50% ceramic dust content has a water saturation equal to 3.7, which is close to the maximum allowable value, therefore a further ceramic dust increase in the composition of the asphalt concrete mixture is impractical.

The results of determining the strength of asphalt concrete under compression (at 50 °C) show that with an increase in the amount of ceramic dust in the composition of asphalt concrete, the strength increases within the limits established by GOST 9128-2009 (not less than 1 MPa). This is due to the shape of the material being introduced, which provides greater adhesion of the material: the sand has a broken form of particles, ceramic dust is angular. Due to its particle size, sand has size module 2.08 (medium), ceramic dust - 1.96 (fine), ceramic dust fills the voids in the asphalt concrete mixture, making it denser and stronger.
At the same time, the increase in the amount of ceramic dust in the composition of asphalt concrete does not significantly affect the ultimate compressive strength (at a temperature of 20 °C). At the same time, all the values found do not exceed 2.2 MPa, which corresponds to GOST 9128-2013 "Mixes of asphalt concrete, polymer asphalt concrete, asphalt concrete, polymer asphalt concrete for highways and airfields. Technical conditions".

The characteristics of the shear stability of asphalt concrete, such as the average work under uniaxial compression and the average work under compression according to the Marshall scheme, are not standardized by GOST 9128-2009, they are necessary to determine the internal friction coefficient and shear adhesion. The definition of the internal friction coefficient shows the values of this indicator are below the limit of 0.81 set by GOST, when using ceramic dust in the composition of the asphalt concrete mixture. This indicator depends on the amount of mineral components and bitumen, therefore, to increase the internal friction coefficient, it is necessary to revise the composition of asphalt concrete and the amount of bitumen.

The second indicator of shear stability - shear adhesion corresponds to GOST 9128-2009 (not less than 0.35 MPa). From an analysis of the results presented in Table 2, it follows that with an increase in the amount of ceramic dust in the composition of asphalt concrete, the shear adhesion decreases, but it remains much higher than the net mix.

Asphalt concrete water resistance when using ceramic dust in composition asphalt concrete mix meets the requirements of GOST 9128-2009 (not lower than 0.85%) with the exception of pure mix, which water resistance index is 0.76%. Thus, the use of ceramic dust in the composition of the asphalt mixture improves the water resistance of this material. A lower percentage of water saturation of a pure mix can be increased depending on the accuracy of the asphalt mix composition selection.

Based on the analysis of test results, it is recommended to use asphalt concrete mix in construction, which contains 50% of ceramic dust from the amount of construction sand. In this asphalt mix all the values of the indicators satisfy the requirements of GOST 9128-2009.

For some indicators, there is a deterioration in the properties of the asphalt concrete mix and for some - an improvement in properties compared to the performance of the pure mix. This is due to inaccurate selection of the mix composition. Revision of the asphalt concrete mix composition may improve these results.

3. Conclusion
Waste production - ceramic dust meets the requirements of GOST 8736-93 to fine sand class II, which is used as a filler for asphalt mixes.

The use of ceramic dust in the asphalt-concrete mixture composition as a filler does not change its structure and physical and mechanical properties. Asphalt concrete is recommended for use in construction, in which 50% of sand is replaced by waste.

4. References
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