Technology for the production of modifying additives for concrete and asphalt concrete

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Abstract. The article presents the results of the development of modifying additives for concretes and asphalt concrete, consisting of spherical SiO2 and fullerene, extracted from silicon production waste. The use of these additives can reduce the destruction of asphalt concrete pavements, increase water and frost resistance. The proposed technology is energy- and resource-saving, converting metallurgical production wastes into the class of "associated mineral raw materials" and improving the environmental situation in regions with the presence of metallurgical industries. The paper presents studies of the feedstock and characteristics of waste gases of silicon production, the characteristics of the main technological equipment for the production of modifiers, the instrumental - technological scheme of the production process, the chemical composition and quality indicators of the resulting spherical silicon dioxide. The order and relationship of the processes that make up the technology of the associated additives based on production of silicon have been determined. The economic effect of the use of these modifiers in asphalt concrete pavements is achieved by increasing the durability and increasing the turnaround time.

1. Introduction

One of the most common types of road surfaces is asphalt concrete. In recent years, the speed and traffic density of vehicles has increased. This leads to the destruction of asphalt concrete pavements and, as a result, to the need to make repairs earlier than the standard terms. One of the main reasons for the destruction of road surfaces is the insufficient water and frost resistance of asphalt concrete. However, one of the most effective ways is the use of modifying additives. In modified asphalt concrete, special compositions are used as a binder, including petroleum bitumen and a modifier. Modifiers are additives that change the physical and mechanical properties and structure of asphalt concrete in the right direction.

One of the variants of such modifiers is silicon dioxide [1-5], the other is carbon nanotubes and fullerene-like carbon [6-7]. Both of these components are contained in the dust of the gas purification plant of silicon production [8-11]. There are solutions for the automation of the technological process for the production of such modifiers. It is also worth noting the high importance of creating modifying additives specifically from production waste in order to improve the environmental situation [12].
2. Characteristics of raw materials, basic technological materials and equipment

The raw material for the associated production of modifying additives for concrete and asphalt concrete is dust from the gas cleaning system, waste gases from the ore-thermal furnace. The characteristics of waste gases from the production of silicon in an ore-thermal furnace are shown in Table 1.

**Table 1. Characteristics of gases removed from ore-thermal furnaces.**

| P/p No. | Parameter name                                                                 | Value         |
|--------|-------------------------------------------------------------------------------|---------------|
| 1      | Power of ore thermal furnaces (RTP), MVA                                      | 16.5          |
| 2      | Volumes of gases removed from the furnace umbrella, nm³/h                      | 200 000       |
| 3      | Temperature of gases removed from the furnace umbrella, °C                     | 230-260 peak to 350 |
| 4      | Volumes of gases removed from the taphole of the furnace, nm³/h               | 70 000        |
| 5      | Temperature of gases removed from the taphole of the furnace, °C              | 60-80         |
| 6      | Dust content of gases removed from the taphole of the furnace, g/nm³          | 0.697         |
| 7      | Concentration of pollutants in gases at the outlet of the furnace compartment, g nm⁻³: |               |
|        | - of dust SiO₂                                                                  | 3.0           |
|        | - SO₂                                                                         | 0.042         |
|        | - NOₓ                                                                         | 0.04          |
|        | - CO                                                                          | 0.122         |
| 8      | Chemical composition of dust, %:                                              |               |
|        | - SiO₂                                                                        | 84.3          |
|        | - Fe₂O₃                                                                       | 0.6           |
|        | - Al₂O₃                                                                       | 1.0           |
|        | - CaO                                                                         | 2.1           |
|        | - C_free                                                                      | 12.0          |
| 9      | Dispersed composition of dust, %:                                             |               |
|        | - less than 30 microns                                                        | 73            |
|        | - more than 30 microns                                                        | 27            |
| 10     | Physical properties of dust:                                                  |               |
|        | - bulk density, g/dm³                                                          | 200           |
|        | - angle of repose, degrees static                                             | 72            |
|        | dynamic                                                                       | 52            |
|        | - abrasiveness                                                                | yes           |
|        | - explosion and fire hazard                                                   | no            |
|        | - wettability                                                                 | 97            |
|        | - specific electrical resistance (resistivity), Ohm·m                         | 10¹¹          |

2.1. Characteristics of the main equipment

The equipment used in the associated production of modifying additives for concrete and asphalt concrete based on the dust of the gas cleaning system is shown in Table 2.
Table 2. The equipment used in the associated production of modifying additives for concrete and asphalt concrete based on the dust of the gas cleaning system in the production of silicon.

| Pos. | Name                              | Destination                                                                 |
|------|-----------------------------------|-----------------------------------------------------------------------------|
| RH   | Receiving hopper                  | Feeding the initial dust by the auger into the RP                           |
| WC1  | Water capacity                    | Water storage and supply to RP                                              |
| RP   | Repulpator                        | Mixing of initial dust from PH with water from WC1                          |
| FM   | Flotation machine                  | Flotation of nanotubes and deposition of SiO$_2$ nanoparticles              |
| CF   | Capacity of flotation reagents     | Storage and supply of flotation reagents in FM                              |
| F1   | Drum vacuum filter                | Primary drying                                                              |
| B1   | Rotary calcining bake 1           | Calcining the chamber product from F1                                       |
| R    | Reactor                           | Washing of foam product from FM with hydrofluoric acid from AC              |
| AC   | Acid capacity                     | Storage and supply of hydrofluoric acid in R                                |
| WC2  | Water capacity                    | Storage and supply of water to the power supply unit                        |
| F2   | Drum vacuum filter                | Separation of acid and foam after R                                         |
| WT   | Foam product washing tank         | Washing the dried foam product                                              |
| C    | Coagulator                        | Thickening of solid phase                                                   |
| CT   | Coagulant tank                    | Coagulant supply in C                                                       |
| F3   | Drum vacuum filter                | Drying of carbon product                                                    |
| B2   | Bake                              | Calcining the carbon-containing product                                    |
| FL1, FL2 | Filling lines                   | Packaging products                                                          |

2.2. Hardware-technological scheme

Figure 1. Technological scheme for the production of modifying additives for concrete and asphalt concrete based on dust from waste gases in the production of silicon.
The technological process must comply with the requirement:

- POT RM 016-2001 "Interindustry rules on labor protection (safety rules) when working in electrical installations."

Measures to ensure industrial fire safety and working conditions must comply with the legislative norms and requirements of the Russian Federation.

The equipment used must ensure the safety of work during operation and repair, comply with the requirements.

### Table 3. Chemical composition and quality indicators of the nodular silicon dioxide of the modifying additive.

| Indicator name                  | Indicator values          | Method of measurement |
|---------------------------------|---------------------------|-----------------------|
| Mass fraction,%:                |                           |                       |
| SiO₂                            | not less than 98          | EN 196-2              |
| CaO                             | no more than 0.3          | EN 451-1              |
| SO₃                             | -                         | EN 196-2              |
| K₂O                             | no more than 0.3          | EN 196-2              |
| Na₂O                            | no more than 0.1          | EN 196-2              |
| Fe₂O₃                           | no more than 0.1          | GOST 2642.5-97        |
| Al₂O₃                           | no more than 0.3          | GOST 2642.4-86        |
| MgO                             | no more than 0.2          | GOST 2642.8-97        |
| P₂O₅                            | -                         | GOST 2642.10-86       |
| Cl                              | -                         | EN 196-2              |
| H₂O                             | no more than 0.3          | GOST 2642.1-86        |
| SiC                             | -                         | GOST 26564.1-85       |
| C_free                          | -                         | GOST 2642.15-97       |
| pH                              | 7.5±0.5                   | GOST 2642             |
| Mass fraction of losses on ignition at 950°C, % | no more than 0.8          | EN 196-2              |
| Surface area (by BET), m²/g     | not less than 16          | ISO 9277              |
| Bulk density, kg/m³             | to 360                    | GOST R 54246-2010     |

The developed technology:

- describes the technology for the production of modifying additives for concrete and asphalt concrete based on dust from waste gases in the production of silicon;
- establishes requirements for the quality of raw materials and materials used for the production of modifying additives from the waste gases of the ore-thermal furnace for silicon production;
- determines the order and interrelation of the processes that make up the technology of the associated production of modifying additives based on carbon in the production of silicon.

The developed technology contains provisions, the implementation of which is mandatory for all technological personnel of the workshop for the production of modifying additives for concrete and asphalt concrete. Additives produced using this technology can act as modifiers for concrete and asphalt concrete of highways.
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