Use of glauconitic sand as a filler in the concrete mixes production

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Abstract. In recent years, any production tries to minimize labor costs by automating processes. Because of the high rate of automation, machines have come to replace people. In addition to reducing the share of human labor and increasing machine labor, any manufacturer seeks to reduce the cost of raw materials, which contributes to the search for new solutions in the use of old materials. Russia’s natural resource base is quite diverse, with special attention paid to the processing of technogenic waste and the creation of resource-saving technologies. Waste generation occurs at all stages of the movement of raw materials: from the moment of its extraction, when it is still a natural resource, to the end of operation of the product made from it. Waste dumps are a rich source of raw materials for the construction materials industry, as many of them are close to natural raw materials in their composition and properties. The complex physical and chemical composition and structure of waste from a number of industrial productions allow considering them as a real raw material base for the construction materials industry. The paper describes the principles of selecting the composition of concrete on glauconitic sand. Glauconitic sand is a waste product, which is why its use reduces the cost of concrete mixes and products made from them.

1. Introduction
Due to the active use of natural resources, the processing of huge volumes of rock mass, water and air is accompanied by a continuous increase in waste[1-2]. The sources of which include chemical, petrochemical, oil refining, energy, metallurgy, and other enterprises that allocate significant funds for their storage. One of the most extensive industries is the construction materials industry, where the share of raw materials reaches 50%. It allows using a large amount of waste, many of which are close to natural raw materials in their composition and properties [3-4]. At the same time, the accumulated scientific and practical experience in the use of industrial waste in Russia and abroad allows considering it as a valuable raw material for the production of construction materials [5-7].

In the Bryansk region, the agricultural and industrial enterprise LLC “PHOSPHATES” is developing the Polpinsky Deposit of natural phosphorite for the production of mineral fertilizers, such as phosphor flour. But a valuable mineral is not only phosphor flour, which is used in agriculture as a fertilizer, but also the main waste from the extraction and processing of phosphorites – quartz-glauconitic sand. Quartz-glauconitic sand is removed during ore processing and stored in landfills. Currently, the accumulated sand is not used in practice.
2. Materials and methods
The most important component of this waste is glauconite. Glauconite is a mineral, an aqueous aluminum silicate of iron, silica and potassium oxide of non-permanent composition, belongs to the group of hydromica. The chemical composition of glauconites from various deposits varies widely. Features of the chemical composition and structure of the mineral have a significant impact on its properties [8]. Numerous studies have established that glauconite is characterized by a rich elemental composition. Unlike natural sands, which are monomineral in their composition and are mainly represented by quartz, glauconite sand contains illite, apatite, glauconite and small amounts of hematite. The chemical composition of sand was determined using x-ray phase analysis, which was performed on a general-purpose x-ray diffractometer (DRON-3M) using the powder method in the range of double angles $2\theta = 4-56^\circ$. Diffraction patterns of samples were taken in the automated mode of the device using the PELDos program, which indicates the predominance of silicon oxide, which accounts for up to 90.1%.

Table 1 shows the main oxides that make up glauconitic sand.

| Oxide  | Content, % |
|--------|------------|
| SiO$_2$ | 83.2-90.1  |
| Al$_2$O$_3$ | 1.1-1.3   |
| Fe$_2$O$_3$ | 1.9-2.2  |
| FeO   | 0.41-0.46  |
| TiO$_2$ | 0.13-0.15 |
| CaO   | 1.5-2.0    |
| MgO   | 0.3-0.5    |
| K$_2$O+Na$_2$O | 1.1-1.2 |
| P$_2$O$_5$ | 1.2-1.4  |
| SO$_3$ | 0.2-0.4   |
| F     | 0.11-0.13  |

The content of organic impurities does not exceed 1%, which is due to the hydraulic method of removing the host rock (glauconitic sand) during the extraction of apatite ores. The true density of glauconitic sand is 2620 kg/m$^3$. The bulk density of glauconitic sand is 1400 kg/m$^3$. The content of organic impurities does not exceed 1%. Voidness is 46.4%. Table 2 shows radiological studies of sand.

Table 2. Radiological studies of the sand of the CC “AIP-PHOSPHATES”.

| Determined indicators            | Measure unit | Research results |
|----------------------------------|--------------|-----------------|
| Specific activity (Ara), $^{226}$Ra | Bq/kg       | 132.8±18.8      |
| Specific activity (ATh), $^{232}$Th | Bq/kg       | 5.6±4.1         |
| Specific activity (AK), $^{40}$K   | Bq/kg       | 118.8±47.5      |
| Level of effective specific activity of natural radionuclides | Bq/kg | 150.7±20.0 |

The grain composition of sand varies by Mk from 1.12 to 1.4 depending on the layers of production. The grain composition is shown in figure 1 as dispersion curves.
Figure 1. Graphical representation of the screen analysis curve of glauconitic sand of different size modulus: a – Mk – 1.12; b – Mk – 1.2; c – Mk – 1.4; d – Mk – 1.65.

The microstructural features of sand were studied using a high-resolution scanning electron microscope (up to 1 nm) TESCAN MIRA 3 LMU, which includes an energy-dispersive spectrometer (EMF) X-MAX 50 Oxford Instruments NanoAnalysis for electron-probe microanalysis.

Analysis of the results showed that quartz grains have a rounded shape and this confirms its marine origin (Fig. 2).

In addition to quartz grains, the sand consists of conglomerates of 100-800 microns in size, consisting of apatite-cemented quartz grains of 0.2-50 microns in size. There are also larger ones up to 200-300 microns.

At higher magnification, they can see the layered structure of this sand, as it is a product of biotite decomposition and belongs to ferruginous hydro mica of variable composition. Its negatively charged lattice consists mainly of leafy aluminum silicate structures.

Thus, glauconitic sand from this quarry can be used in all types of construction, belongs to the 1st class of building materials, including for heavy and light concrete, for filling roads, without restrictions on the radiation factor [9-10]. All types of transport are allowed. Based on the results of radiological studies, it was found that the measured values of the content of natural radionuclides in the sand correspond to the standard values for 1 class building materials.

3. Results and discussion

According to the test results, it was found that the sand is classified according to GOST 8736-2014 “Sand for construction works. Technical conditions (as amended)” [11] as very small (Mk-1.12) or fine (Mk-1.65). It was also found that concretes on various types of cement with glauconitic sand have lower strength values compared to concrete on quartz sand. At the same time, the modulus of sand size
was similar, and the mobility of the concrete mix with glauconitic sand was 15-25% less than on quartz sand. This is due to the ability of glauconite contained in sand to absorb a significant amount of water compared to quartz. The results of research have shown that the water demand of the concrete mixture for obtaining a given mobility is directly proportional to the amount of sand in the mixture [12]. Excessive water content contributes to the formation of a less dense structure and leads to a significant increase in porosity.

To obtain equal strength concrete in comparison with the traditional aggregate – quartz sand, it is necessary to increase the cement content, which leads to its overspending. Despite the overestimated cement consumption when using glauconitic sand in a concrete mix, the calculation of economic efficiency shows the feasibility of using this sand as a fine aggregate. According to the calculations (table 3) the cost of concrete on quartz sand is 4410 rubles/m³.

**Table 3.** Cost calculation for B25 P4 using quartz sand.

| Name of the material | Material consumption per 1 m³, kg | Price, ruble/kg | Involved cost, ruble/kg |
|----------------------|-----------------------------------|-----------------|-------------------------|
| Cement               | 340                               | 5.5             | 1870                    |
| Sand, Mkr=1.7        | 780                               | 0.38            | 296.4                   |
| Rubble fractions 5-20 mm | 1150                           | 1.9             | 2185                    |
| LST                  | 2.72                              | 20              | 54.4                    |
| Water                | 185                               | 0.02            | 3.7                     |
| **Production cost of 1m³** |                                |                 | **4410**               |

When replacing quartz sand with glauconite, keeping all other parameters, we get the cost of 4152 rubles/m³ (table 4).

**Table 4.** Cost calculation for B25 P2 using glauconitic sand.

| Name of the material | Material consumption per 1 m³, kg | Price, ruble/kg | Involved cost, ruble/kg |
|----------------------|-----------------------------------|-----------------|-------------------------|
| Cement               | 340                               | 5.5             | 1870                    |
| Sand, Mkr=1.65       | 780                               | 0.05            | 39                      |
| Rubble fractions 5-20 mm | 1150                           | 1.9             | 2185                    |
| LST                  | 2.72                              | 20              | 54.4                    |
| Water                | 185                               | 0.02            | 3.7                     |
| **Production cost of 1m³** |                                |                 | **4152**               |

It is worth noting that with glauconitic sand on a given amount of water, we got the mobility of P2 instead of P4. The net savings while maintaining all parameters is 257 rubles/m³. However, due to the high water demand of sand, in order to maintain the water-cement ratio and obtain the required mobility of P4, it is necessary to adjust the cement consumption (table 5).
5.

**Table 5.** Calculation of the cost of B25 P4 using glauconitic sand.

| Name of the material         | Material consumption per 1 m³, kg | Price, ruble/kg | Involved cost, ruble/kg |
|------------------------------|----------------------------------|-----------------|-------------------------|
| Cement                       | 360                              | 5.5             | 1980                    |
| Sand, Mkr=1.65               | 760                              | 0.05            | 38                      |
| Rubble fractions 5-20 mm     | 1150                             | 1.9             | 2185                    |
| LST                          | 2.88                             | 20              | 57.6                    |
| Water                        | 185                              | 0.02            | 3.7                     |
| **Production cost of 1m³**   |                                  |                 | **4264**                |

In this case, with increased cement consumption, the net savings are 145 rubles/m³. The strength and mobility are similar to those of a concrete mix on quartz sand.

4. **Summary**

Thus, the use of technogenic glauconitic sand as a fine aggregate for ordinary concrete allows preserving all the physical, mechanical and operational characteristics of the mixture and finished products. At the same time, the use of this sand reduces the cost of concrete mix and solves the problem of storing technogenic waste.

5. **References**

[1] Kikava O Sh, Solomin I A Construction waste recycling *Moscow 2000*

[2] Kalgin A A, Fakhratov M A, Kikava O Sh, Baev V V Industrial waste production of building materials *Moscow 2002*

[3] Suleymanova L A, Erokhina I A, Suleymanov A G 2007 Resource-saving materials in construction *Proceedings of higher educational institutions. Construction* 7 113–116

[4] Tolstoy A D, Lesovik B S, Milkina A S 2018 Features of the structure of new generation concrete using technogenic materials *Bulletin of the Siberian State Automobile and Road University* 15 (4) 588-595

[5] Al-Bu-Ali U S, Lesovik R V, Kharkhardin A N, Tolstoy A D, Akhmed A A A, Alaskanov A Kh, Aynov Zh T 2020 Calculation and selection of grain composition of aggregate from high-density concrete scrap packaging *Bulletin of BSTU named after V G Shukhov* 6 18-28

[6] Akhmed A A, Fedyuk R S, Liseytsev Yu L, Timokhin R A, Murali G 2020 Use of Iraqi concrete scrap as a filler and aggregate for heavy and light concrete *Construction Materials and Products* 3(3) 28-39

[7] Onoprienko N N, Salnikova O N 2019 Improving the efficiency of construction solutions of domestic production *Bulletin of BSTU named after V G Shukhov* 8 22-29

[8] Tolstoy A D 2020 Fine grained high strength concrete *Construction Materials and Products* 3 (1) 39-43

[9] Bazhenov Yu M 1975 “Method for determining the composition of various types of concrete”

[10] Suleymanova L A, Lesovik R V, Glagolev E S, Sopin D M 2008 High-quality concretes on technogenic raw materials for critical products and structures *Bulletin of BSTU named after V G Shukhov* 4 34–37

[11] GOST 8736-2014 “Sand for construction works. Technical specifications (as amended)”
[12] Fomina E V, Vovtovich E V, Fomin A E, Lebedev M S, Kozhukhova N I 2015 Assessment of the radiation quality of OEMK slag for its use in construction composites Bulletin of BSTU named after V G Shukhov 6 130–133.

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