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Ways for Recycling of Quartz Waste in the Production of Silicate Materials

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Abstract

The technological properties of quartz waste associated with the clay deposit are investigated by way of emission spectral analysis, petrography and X-ray phase analysis. This study considers the possibility of quartz waste utilization in the production of dry building mixtures as a filler, magnesia-quartz proppants as a raw material component, cement as a siliceous component, fine ceramics as a partially fluxing and exhausting component, silicate brick as the main raw material. In the production of glass and glassware it is possible to make use of the quartz waste as a glass-forming component including silicate blocks after refining for the Al_2O_3 and Fe_2O_3 content. Quartz waste can be recommended as molding sand after refining for the contents of Fe_2O_3, Na_2O, K_2O, MgO, CaO. Improvement of the properties of the quartz waste can be achieved by ways of elutriation to remove the clay component as well as magnetic separation to remove magnetic compounds of iron.

Keywords: quartz waste, proppants, glass, cement, silicate brick, building mixtures, fine ceramics, molding sand, recycling

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1. Introduction

Given the current state of consumption of natural raw materials, the utilization and involvement of secondary material resources in social production is significant. The integrated use of raw materials and waste is also associated with solving the problem of non-waste and environmentally friendly technologies creation [1]. A special interest is the use of technogenic raw materials which, on the one hand, ensures the saving of natural raw materials and, on the other hand, allows it to be disposed of improving the environmental situation [2, 3]. To use local raw materials, it is necessary to develop new effective technologies or improve existing methods to produce silicate materials [1]. This article deals with the utilization of quartz waste after extraction of titanium-containing components.

From the geological point of view the quartz sand is a sedimentary fine-grained, non-cemented rock consisting of mineral grains of 0.005–2.0 mm in size. Quartz sand is a conglomerate, sedimentary rock, comprising mainly by quartz grains [4].

There are clay deposits on the territory of Tyumen region (Russia). The potential of this raw material has not been sufficiently studied for the construction industry [5, 6]. The aim of this work is to study the possibility of using quartz waste of raw materials after extraction of titanium-containing components to obtain dry building mixtures, proppants, cement and silicate brick, glass and glassware, fine ceramics and its use as molding sand.

2. Experimental Procedure

The chemical composition of quartz waste was determined by emission spectral analysis with inductively coupled plasma using Optima 4300 DV optical emission spectrometer (Perkin Elmer, USA). The grain composition, modulus of sand fineness and true density using the pycnometric method were determined in accordance with [7]. Petrographic studies of refractory products were carried out in reflected light by optical microscope Polam R-311.

3. Results and Discussion

This paper presents the experimental results of possible utilization of quartz waste depositing in Tyumen region (Russia) in the production of silicate materials.

The suitability of quartz waste for construction work was examined accordance with [8]. The grain composition and modulus of sand fineness determined in accordance with [7] are presented in Table 1 (Author's own work).

Table 1: Grain composition of quartz waste.

Sieve residue	Fraction content, mass %, mm							
	2.5	1.25	0.63	0.315	0.16	0.1	0.004	0
partial	3.5	2.0	1.5	1.2	12.1	67.47	11.97	0.26
full	3.5	5.5	7	8.2	20.3	87.77	99.74	100

The full residue on sieve No. 063 is 7% (see Table 1) which corresponds to a very fine sand. Quartz waste visually contains large pieces (more than 5 mm). When sifted these pieces are easily destroyed and the entire sample of quartz waste passes through a No. 5 sieve, i.e. this quartz waste does not contain particles larger than 5 mm. A particle content of less than 0.16 mm is 79.7% which allows quartz waste to be classified as very fine sand. The class of quartz waste corresponds to II with a particle size modulus of 0.44 [8].

The clay content in the quartz waste clots is 5% and for fine and very fine sands should not exceed 1%. The content of dusty and clay particles in the quartz waste is 5.6% which is in agreement with [8] (up to 10%).

Due to the presence of organic impurities the quartz waste is suitable for use in concrete and mortars since the liquid above quartz waste sample has been slightly colored. The optical density of the liquid above the waste is 0.044 compared to a standard solution with an optical density of 0.6–0.68.

The true density of quartz waste determined by the pycnometric method [7] is 2647 kg·m^{-3}. The bulk density of waste is 1339 kg·m^{-3}, the voidness is 49.4% and the absolute humidity is 0.5%.

The reactivity of quartz waste is 37.24 mmol/l which meets the requirements of [8] (not more than 50 mmol/l). The quartz waste contains a permissible amount of amorphous varieties of silicon dioxide soluble in alkalis (chalcedony, opal, flint, etc.). Quartz waste can be used as filler for concrete due to its resistance to the chemical effects of alkali cement.

The sulfide sulfur content in the quartz waste is 0.0043% and the sulfate sulfur one is 0.015%. According to [8] sulfur, sulfides, except pyrite (marcasite, pyrrhotite, etc.) and sulfates (gypsum, anhydrite, etc.) in terms of SO_3 should be no more than 1.0%, pyrite in terms of SO_3 not more than 4% by weight. Therefore, the quartz waste under investigation is suitable for use as filler for concrete and mortar.

For the suitability of the quartz waste in road construction the content of clay particles by the swelling method was determined [8]. The increment of the material volume in the quartz waste was not observed. The quartz waste under study can be used in road construction.

Thus, quartz waste can be used as filler of heavy, light, fine-grained, cellular and silicate concrete, mortar, production of dry mixes as well as for the construction of bases and coatings of roads and airfields after removing clay in clots by elutriation or dry sieving way.

For the utilization of quartz waste in proppant production the chemical composition and particle size distribution of waste are determined [9, 10]. The chemical composition of quartz waste is presented in Table 2 (Author's own work).

Table 2: Chemical composition of quartz waste.

Component	Al_2O_3	BaO	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	Mn_2O_3	Na_2O	SiO_2	TiO_2
Weight content, %	4.274	0.0541	0.239	0.014	1.179	2.075	0.107	0.0437	0.679	88.181	1.122

According to [9] the MgO content should be at least 8%. The MgO content in waste is 0.107% (see Table 2) which does not meet the requirements of the state standard. According to [10] the Al_2O_3 content should be at least 50%. In the waste it is 4.274% which also is out of line the requirements. In addition, the minimum size of proppants defined by standards is 0.212 mm. The waste in the bulk (80–90%) consists of particles with a size not exceeding 0.16 mm. Thus, quartz waste can be used as a raw silica-containing component to produce proppants.

The possibility of using quartz waste as molding sand in foundry is investigated. According to [11] the content of silicon dioxide should be at least 90.0% and the content of SiO_2 in the waste is 88.181% (see Table 2) which does not correspond to the required characteristics. In addition, the content of harmful impurities Fe_2O_3 in the waste is 1.179% and according to GOST it should be no more than 1%. The total content of Na_2O+K_2O+MgO+CaO is 3.1% and according to GOST it should not be in excess of more than 2%.

Thus, the quartz waste does not meet the requirements of the state standard in terms of chemical composition and cannot be recommended for use as molding sand due to the higher content of fluxing oxides.

State standards defining the requirements for sand to produce silicate brick and cement do not exist. Until 2002 there was an industry standard [12] which presented the following requirements for sand: particle size modulus is up to 2, moisture content is up to 8%, dust content, clay, clay mud is not more than 10%, the content of organic impurities is not darker than the color of the standard, the average density is not less than 1200 $kg{\cdot}m^{-3}$, the content of quartz (unbound SiO_2) is not less than 50%.

The particle size modulus of quartz waste is 0.44, the content of dusty, clay and clay impurities is 5.46%, humidity is 0.5%, the quartz content determined according to [13] is 86.9% which corresponds to industry standard requirements.

To produce silicate brick, the mountain and ravine sands consisting of sand grains of an acute-angled shape with a rough surface which contributes to their good adhesion to lime are desirable. River and lake sands containing rounded sand grains with a smooth surface do not adhere well to lime [14]. Petrographic studies of quartz waste showed that grains have a predominantly rounded shape.

Due to its high dispersion and clay components content the quartz waste can be claimed as a siliceous type of raw material to produce Portland cement.

To study the possibility of using quartz waste in the production of glass and glassware, [15] is used. It was established that the quartz waste does not meet the standard requirements for the T brand to produce bottle green and dark green glass in chemical composition: Al_2O_3 content is 4.274%, and the content SiO_2 is 88.181%. According to

GOST content should be up to 4.0% and not less than 95% respectively. For all other grades the waste does not meet the requirements [15] for the Fe_2O_3 content. The content of iron oxide is 1.179% (see Table 2) by contrast to the requirements of GOST (up to than 0.25%).

To produce silicate blocks, the quartz sands of grade B-100-1 are used [15]. The chemical composition of sand should meet the following requirements: Al_2O_3 content is not more than 0.6%, Fe_2O_3 content is up to 0.1%, SiO_2 content is not less than 98.5%. On account of all three indicators the quartz waste does not meet the specified requirements.

By grain composition the fraction content of less than 0.1 mm should be no more than 10% for unenriched sands. The quartz waste under study contains 12.25% fractions of less than 0.1 mm (see Table 1).

Thus, quartz waste can be used in the glass industry including the production of silicate blocks after appropriate refinement in the content of SiO_2, Al_2O_3 and Fe_2O_3 and removal of the fraction of less than 0.1 mm.

The possibility of using quartz waste in the production of fine ceramics is determined. According to [16] the sand does not comply with the following indicators: SiO_2 content should be not less than 93%, the total content of Fe_2O_3+TiO_2 should be not more than 0.3%. In the waste sample they are 88.181% and 2.31% respectively.

Petrographic studies showed that the source clay contains hydromica (muscovite and biotite) in an amount of 10–15%. To produce ceramic tiles, in particular for the internal wall cladding and for floor tiles the clay, alkali-containing components (meshes) and sands are always introduced into the mass composition. Therefore, the studied quartz waste can be claimed by manufacturers of ceramic tiles including porcelain.

4. Conclusion

The principal possibility of obtaining silicate materials based on quartz waste remaining after extraction of titanium-containing components from raw materials is shown. The basic technological properties of quartz waste were studied. The parameters were examined for compliance with the requirements of state standards used in the production of silicate materials.

The quartz waste under study can be recommended as a filler for heavy, light, fine-grained, cellular and silicate concrete, mortar, and preparation of dry mixes. The quartz waste can be claimed as a raw material component to produce ceramic tiles including porcelain stoneware as well as proppants. Quartz waste can be used in the glass industry including in the production of silicate block after appropriate refinement in the content of Al_2O_3 and Fe_2O_3 and removal of fractions less than 0.1 mm.

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