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On the potential use of basalt waste as mineral fillers

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Abstract. Producing present-day constructional materials on mineral binders is directly connected to the use of micro- and ultra-disperse technogenic modifying agents. They allow to obtain the maximum particle-particle packing in composition, provide rational raw mix design, contribute to structure formation process. The present article is devoted to the investigation of searching the most rational solution for the problem of basalt waste utilization, with the basalt waste being the valuable secondary raw material resource. The studies have shown that it is possible to use basalt dust as admix to gypsum composites. The basalt waste, by changing the composition grain-size distribution, provides the better particle-particle packing both for fine-grained and coarse waste fractions, thus having positive effect on modified gypsum rock structure. Optimization of internal structure also contributes to the increase of gypsum rock strength properties. The obtained gypsum composite can be profitably employed for manufacturing small-piece walling gypsum materials by casting process.

1. Introduction

Producing present-day constructional materials and concretes based on mineral binders is directly connected to the use of micro- and ultra-disperse modifying agents. They allow to obtain the maximum particle-particle packing in composition [1, 2, 3], provide rational raw mix design, contribute to structure formation process, and they are also able to perform other functions [4-7]. Such modifying agents can be obtained from natural [7] and technogenic sources [8-10], with the high priority of using technogenic raw materials as such admixes. This is due to the availability of such resources, their low cost, as well as to the ecological aspects of their use. Development of resource-saving technologies allows to preserve the natural environment for the future generations.

Today the resource-saving technologies mostly mean the technologies providing the minimal use of primary natural resources during all the production stages. But they should also provide the processing of waste into secondary raw material resources, first of all the large amounts of waste generated at production units. It is the waste processing that is not always properly implemented at production units. That is why it cannot be rated as resource-saving, even with the availability of studied and cost-effective production technology.

The process of basalt fiber production was conceived and improved in 1961, in the Soviet Union. At present it might be classified as insufficiently power-intensive, as during the last 20 years the special low-power consumption units for melting and stretch-forming of basalt fiber have been developed and implemented [1]. However, even this process of basalt fiber production still cannot be called a resource-saving one. Presently up to 15% of waste from the total amount of basalt wool and fiver production is land-buried.

At the same time, it is exactly the basal fiber consumption in our country that has been increasing with every year. The reason is its obvious advantage over other fiber variants in physical-mechanical, performance, economical and other factors.

The areas of waste burial sites have been accordingly increasing with every year as well. The large allocation of land for waste burial sites cannot help affecting the whole ecology situation [2, 3]. Such waste materials, as well as fiber itself, are fire-resistant, chemically stable and safe for humans. They are suitable for realization as secondary raw material resources.

It is also necessary to take into account the world tendency in waste management, that consists of partially replacing construction material components by waste materials [4].

If we follow this tendency, it will be possible to make the process of basalt fiber production a resource-saving one to the full extent.

Basalt fiber itself as reinforcement material has proved itself to be good and it is widely used in various industries: machine-building, car manufacturing, building and construction, an even in sport equipment manufacturing.

Basalt fiber production is accomplished in the following stages: fragmentation of basalt, melting of basalt chips in melting furnaces, and continuous fiber drawing. Later on, fiber can be used as finished product or can be woven into fabric, mats and nets. Fiber and fiber-based materials are lightweight, durable, chemically resistant to aggressive environments. The production costs are less for basalt fiber than for alum and carbon-fiber. The use of basalt materials provides environmental and fire safety for materials and environment. Thus, they can be used, without restrictions, in all the production and consumption spheres [1].

Many authors have studied the potential of using various rocks, their fragmentation waste products as fillers in construction mixes, and also as raw materials for mineral binders, including gypsum binders [13, 14].

Gypsum is widely used as a binder. He has several superior properties, including; low density, good heat and sound insulation, volumetric stability, thermal and fire resistance, easy fabrication, manufacturability, low price and attractive appearance [15].

However, despite these superior properties of gypsum, so is concern regarding its strength, setting time, water absorption and strength. To tackle such inferior properties, attempts have been tried by numerous research work, in which the focus has primarily been on modifications of gypsum matrix using different mineral admixtures and reinforcing materials – to the creation of composite binders [15].

The addition of different dispersed minerals admixtures (e.g. clay minerals, lime, silica fume, microcalcite, pounded glass, Portland cement, cork) can assist in modifying the chemical and physical properties of gypsum, resulting in positive influences on its fresh and hardened properties [15].

The authors of article [8] view the particulars of using technogenic raw materials in composite binders on the gypsum. Article [9] deals with researching heat insulating materials with the similar waste used as components. It has been established that mineral modifiers make it possible, above all, to increase such quality characteristics of the resulting mixes and concretes as strength and density [10-14], and the use of waste in them allows to achieve economic effect as well [16-19]. Thus, at present there are two guidelines for utilization of dust-like mineral waste: to be used as a filler or as a binder (its component), subject to its activity excitation [17-18, 20-24].

The present article is devoted to the investigation of searching the most rational solution for the problem of basalt waste utilization, with the basalt waste being the valuable secondary raw material resource.

2. Materials and Methods

The article deals with the α-modification gypsum binder of G-16 grade by Samara gypsum plant of Samara region.

The α-modification gypsum binder of G-16 grade by Samara gypsum plant is characterized by low water demand – 35-40 %, initial setting time of 4-5 minutes and final setting time of 20 minutes.

Grain-size composition is specified by GOST 125 by residue on the sieve of 0,2 mm – 0,5 %. Absorption of water by GOST comprises 18 %. Volumetric expansion does not exceed 0,25 %.

Compressive strength is 16 MPa, bending tensile strength is 6-7 MPa.

Metal impurity content is maximum 10 mg per 1 kg of gypsum.

Size distribution index of dust removal waste of LLC "Paroc" basalt:

- Mean particle size of dust-like waste d50 – 24.866 micron;
- Maximum particle size of waste particles d99 – 111.743 micron;
- Particles less than 2 micron – 9.66 % by mass.

Basalt dust is represented by minerals of plagioclase group, in particular by quartz, calcite, anorthite. Dust-like waste mass is glassy and laced with many pyroxene and plagioclase crystals (Figure 2).

Figure 1. Basalt dust –basalt fiber waste of LLC "Paroc" production unit.

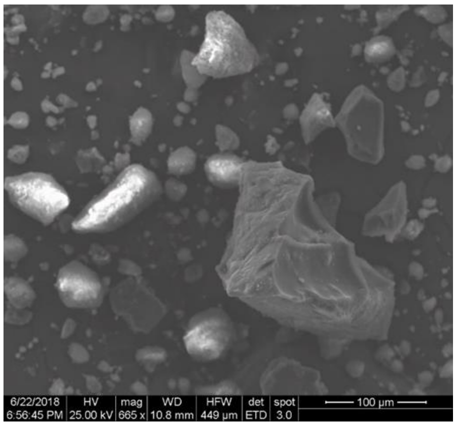

Figure 2. Microstructural photographs of basalt dust of LLC "Paroc".

The studies of basic physical mechanical properties of gypsum composites were conducted in accordance with the requirements of standards GOST 23789, GOST 8462, GOST 7025.

Gypsum paste and gypsum paste-based mixes were prepared by mixing gypsum binder and basalt fiber waste (Figure 3) in the dry state by hand mixer, and then by tempering dry uniform mix with water.

Figure 3. Basalt dust. Appearance of fracture.

For determining the normal consistency of gypsum paste, a clean container was filled with the required amount of tempering water, then the weight of gypsum binder dry powder (or binder with additives) in the amount of 300g was added to this water. The paste was mixed by hand mixer until becoming uniform and then was poured into Suttard form. After 15 seconds from the tempering moment the viscosimeter rose upward vertically. If the flow diameter of the formed gypsum cake comprised (180 ± 5) mm, then the value of water-solid ratio was taken for normal consistency, otherwise the testing continued by changing water content until obtaining the required flow diameter of gypsum paste.

For determining compressive strength limit and bending tensile strength limit for modified gypsum rock, standard test beams were used of 40x40x160 mm dimensions (Figure 4 a). Standard beam testing was conducted by standard methods in accordance with GOST requirements (Figure 4 b, c).

Basalt dust content varied from 0 to 12 % at 2 % interval. Water-gypsum ratio was taken as corresponding to the normal consistency of gypsum paste.

a b c

Figure 4. Materials and methods of testing gypsum binder modified by basalt waste.

3. Results and Discussion

The study results for modifying structure and properties of gypsum rock with basalt waste admix are presented in Figure 5-7.

The study of the basalt waste effect on bending tensile strength limit of gypsum rock is presented in Figure 5.

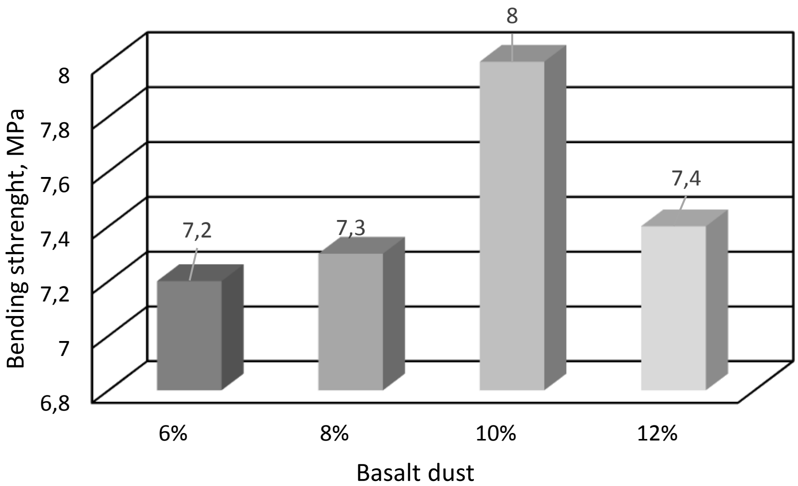

Figure 5. Effect of basalt waste content on bending tensile strength limit.

The resulting data on the evaluation of waste effect on compressive strength limit of modified gypsum rock is presented in Figure 6.

The microstructure of gypsum rock modified by waste is presented in Figure 7. The sample with basalt waste content of 10% by gypsum binder mass had been selected for studying the modified gypsum microstructure.

Inclusion of basalt dust into gypsum binder composition did not considerably affect the bending tensile strength of the obtained rock. The maximum value of bending tensile strength limit is achieved with the admix content of 10% and comprises 7,9 MPa. It is only by 7 % on the average higher than the tensile strength of the control samples (Figure 5), which, on the average, was in the order of 7 MPa.

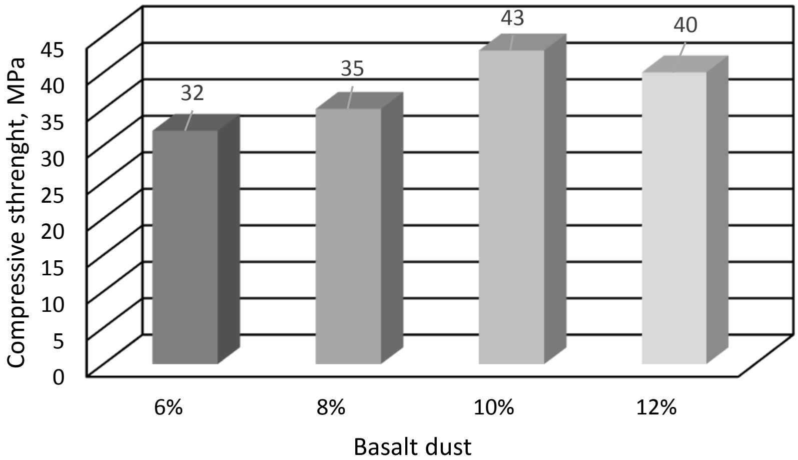

Figure 6. Effect of basalt waste on compressive strength.

To a greater extent the basalt waste affects compressive strength limit. The compressive strength of the samples without admixing basalt dust comprised 30 MPa (Figure 6). The maximum compressive strength was demonstrated by the gypsum rock samples with the composition containing 10% of basalt duct by the gypsum binder mass.

Figure 7. Gypsum rock structure modified by basalt waste.

4. Conclusion

In summary, the studies have shown that it is possible to use basalt dust as admix to gypsum composites. In the context of using this dust for gypsum rock modification, the most efficient use will be with the basalt dust content of 10% by gypsum binder mass. This contributes, first of all, to the increase of compressive strength properties of gypsum rock. Evidently it could be explained by the fact that basalt waste, by changing the composition grain-size distribution, provides the better particle-particle packing both for fine-grained and coarse waste fractions, thus having positive effect on modified gypsum rock structure. Optimization of internal structure also contributes to the increase of gypsum rock strength properties. The obtained gypsum composite can be profitably employed for manufacturing small-piece walling gypsum materials by casting process.

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