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Research Article

Pressed Phosphate Materials Using Dispersed Rocks

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Abstract: The possibility of contact hardening of dispersed rocks after their acid activation by phosphoric acid is shown. The parameters of pressing, content and concentration of phosphoric acid, as well as the values of temperatures during thermal treatment are given. It is established that the obtained pressed phosphate materials (analogs of geopolymers) have high acid resistance, alkali resistance and heat resistance.

***Keywords*:** geopolymers; rocks; phosphoric acid; acid activation; contact hardening

1. Introduction

One of the ways to solve the problem of replacing energy-intensive Portland cement in construction is the development and widespread introduction into production of geopolymer binders and concretes based on them [1]. Most often, such binders are alkali-activated materials [2].

Acid activation of aluminosilicate materials is an alternative option for obtaining geopolymer materials [3–5]. Acid activation of dispersed (mechanically activated) silicate or aluminosilicate crystalline materials may be one of the perspective directions of using rock-crushing waste for making pressed composite materials. One of the most common acid activators is phosphoric acid [6, 7].

V. Glukhovsky [8] proposed a mixed binder based on hydrated materials - belite slurries, which were treated with mineral acids (H_2SO_4, etc.). By increasing the content of hydrosilicates and the formation of other new compounds, such materials acquire the ability to contact hardening. The possibility of acid activation of anhydrous aluminosilicates – granulated slags, noted M. Sychev [9], in particular, when using phosphoric acid. For phosphate binders also use such dispersed materials as slag, sandstone, asbestos, mica, clays, apatite, etc.

We investigated the possibility of acid activation with phosphoric acid of dispersed crushing waste of some crystalline rocks in order to obtain pressed contact hardening materials – analogs of geopolymers.

2. Materials and methods

Waste crushing of crystalline rocks of the Western region of Ukraine - granite, labradorite, basalt, as well as quartz sand were used. The rocks were ground in a laboratory ball mill to a specific surface of 400...450 m^2/kg. The obtained powders were mixed with a solution of phosphoric acid. Mixing was carried out in a laboratory blade mixer for 4–5 minutes. Cylinder specimens with a height and diameter of 25 mm were molded from this material by pressing. The obtained specimens were cured in the air or subjected to thermal treatment at 200°C…600°C.

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3. Results

The results of determining the strength of specimens using dispersed materials as well as granite screenings (not milled) and extraction orthophosphoric acid (H_3PO_4) are shown in Table 1. The pressing pressure was 100 MPa. According to these data, the strength of specimens depends on the concentration of acid, type of material, and method of mixing. When using concentrated solutions of phosphoric acid and double mixed, the strength of the specimens was up to 140 MPa.

Phosphoric acid at a concentration of 42% allows to obtain phosphate materials using dispersed crystalline rock with compressive strength in the range of 20...40 MPa, and this value decreases in the order: sand > basalt > granite > labradorite. The intensity of mixing is essential. Repeated mixing of the material after raw specimen's fracture allowed a significant increase in strength (No.9, Table 1). Studies have shown that changing the firing temperature between 200...600°C has relatively little effect on the materials' strength (Figure 1).

Table 1. Strength of phosphate materials using dispersed rocks

No.	Dispersed material	Concentration of H_3PO_4, %	Liquid-solid ratio	Conditions curing	Compressive strength, MPa
1	Granite	42	0.22	Firing at 400°C	24.6
2	Granite screenings	42	0.083	Firing at 400°C	14.1
3	Labradorite	42	0.22	Firing at 400°C	22.5
4	Sand	42	0.22	Firing at 400°C	32.2
5	Basalt	42	0.22	Firing at 400°C	26.0
6	Basalt[1]	42	0.22	In the air - 7 days	16.1
7	Basalt	80	0.11	Firing at 400°C	21.7
8	Basalt	80	0.22	Firing at 400°C	118.0
9	Basalt[1]	80	0.22	Firing at 400°C	132.1

Note: 1 - Re-mixing was used after fracture of the raw specimen

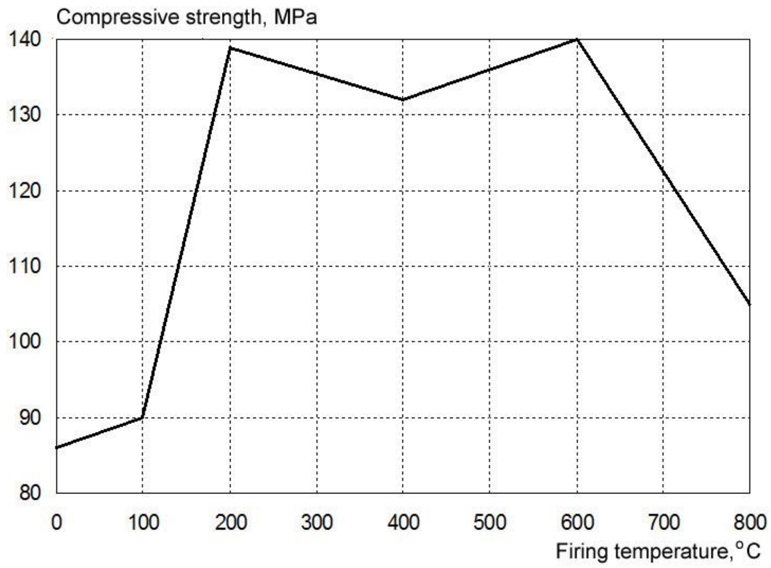

Figure 1. Dependence of basalt-phosphate materials' strength on the firing temperature (Mixture No. 9 was used according to Table 1)

The additive of a small amount of Portland cement allows hardening of phosphate materials without firing, i.e., on air. Granite screenings due to the presence of a significant amount of fine particles (the content of the dust-like and clay particles is about 20%) can form a sufficiently strong artificial stone even without grinding (№ 2, Table 1). Moreover, the necessary acid consumption is only 8%.

A sufficient level of water resistance (water resistance coefficient is more than 0.75) is achieved at a firing temperature of over 300°C and then practically does not change (see Figure 2). In this case, there are irreversible changes in the structure of the artificial stone with the formation of water-unsoluble phosphates and complex compounds. Artificial stone based on dispersed crystalline aluminosilicates and phosphoric acid also has high acid and alkali resistance which is explained by the use of rocks that are chemically resistant. Such materials also have thermal resistance (they can withstand rapid cooling from 800°C to 20°C without significant loss of strength).

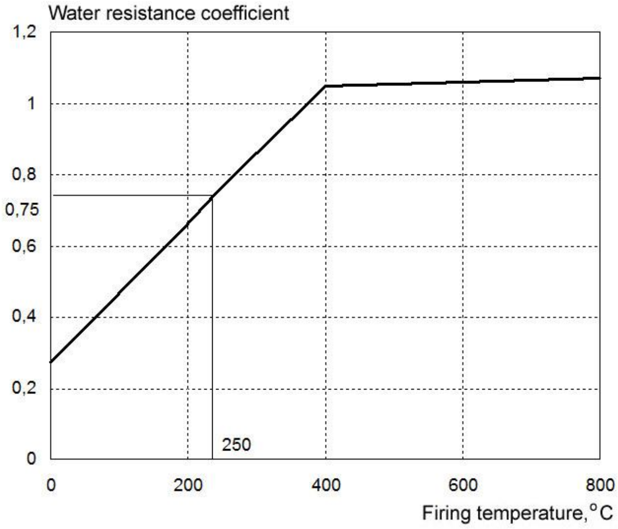

Figure 2. Dependence of water resistance of basalt-phosphate materials on firing temperature (Mixture No. 9 was used according to Table 1)

4. Conclusions

Thus, the use of phosphoric acid as an acid activator of dispersed rock-crushing wastes makes it possible to obtain pressed composite materials of contact hardening, which are analogs of geopolymers. This opens up new opportunities for the utilization of rock processing waste in the construction industry for the manufacture of a wide range of products – lining, wall, cladding, road, etc.

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Conflict of interest

There is no conflict of interest for this study.

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