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PROSPECTS FOR THE USE OF PUMICE FROM GEORGIA IN LIGHTWEIGHT CONCRETES

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Lightweight concrete is a building material with a density not exceeding 2000 kg/m^3. Its structure is determined by the structure of the used components and manufacturing methods. The advantages of these building materials are their low density, good thermal insulation, frost resistance, high thermal resistance, ease of use of blocks, which is due to their large size and low weight; also important is their wide range, which allows one to choose the optimal material composition suitable for operating conditions.

In the production of lightweight concrete, pumice, along with binders, is one of the main components of its composition. These minerals are frothy, have a low volumetric weight, high porosity and high toughness. All these properties make them a valuable mineral raw material mainly used as additives for lightweight concretes and hydraulic cements.

Pumice is abundant in Georgia (more than 35 million m^3). The prospects for the use of these minerals are great, so the study of their physical and chemical properties is relevant and obligatory.

Six pumice samples from four different locations in the Javakheti region of Georgia were studied. Chemical, X-ray diffractometric, infrared spectroscopic, petrographic, and granulometric methods were used for investigations. Chemical and mineralogical composition of the analyzed samples, peculiarities of their structure, as well as bulk and compacted samples volume masses and their granulometric composition were determined.

The slags with the best properties will be recommended as additives for use in the production of lightweight concrete.

***Keywords**: volcanic glass, pumice, lightweight concrete, porous materials*

INTRODUCTION

Lightweight concrete is a building material with a density not exceeding 2000 kg/m^3. Its structure is determined by the structure of the used components and manufacturing methods. The advantages of these building materials are their low density, good thermal insulation, frost resistance, high thermal resistance, ease of use of blocks, which is due to their large size and low weight; also important is their wide range, which allows one to choose the optimal material composition suitable for operating conditions.

Lightweight concrete is made of porous aggregates. Attention is drawn to their high thermal resistance. Various types of porous lightweight concretes which are used in bearing structures, as well as in bearing structures that also perform the function of a thermal insulator are known today. Of the many types of concrete, some are widely used and some are used in limited quantities. Currently, new varieties of concrete have been obtained not yet used in practice, although there is a prospect of their use in the future [1, 2].

In the production of lightweight concrete, pumice, along with binders, is one of the main components of its composition.

Pumice, or porous volcanic glass, is formed during a volcanic eruption in conditions of strong lava boiling. These minerals are frothy, have a low volumetric weight, high porosity and high toughness. All these properties make them a valuable raw material, mainly used as additives for lightweight concretes and hydraulic cements.

Pumice reserves in Georgia exceed 35 million cubic meters [3], so the prospects for their use are very high. Pumice is a variety of acidic volcanic, magmatic rocks formed by volcanic eruptions in the upper layers of acidic lavas, during boiling [4, 5] and differing from each other in the content of silicon in minerals as well as in structural and textural features. There are fibrous, vesicular, frothy and cellular pumice textures. Their structure may be finely-porous or coarsely-porous. The average porosity is 80 %, the density is 2–2.5 g/cm^3, the hardness according the Mohs scale is 5–5.6. The volume weight is 0.3–0.9 g/cm^3. Pumice is chemically inert and begins to soften at 1300–1400 °C [6].

Due to the high porosity, pumice is good thermal insulator, and a large number of closed pores ensure its good frost resistance. Pumice from different deposits has different textures. For its practical use, the size of the pores and the nature of the glassy substances included in its composition are of great importance. According to the SiO_2 content, pumice igneous rocks are divided into acidic igneous (content of SiO_2 is more than 65 %), medium igneous (content of SiO_2 – 65–54 %), basic igneous (content of SiO_2 – 52–45 %) and ultra-basic igneous rocks (content of SiO_2 – below 45 %) [7]. The minerals that form such igneous rocks in most cases are quartz, feldspar and mica. Amphibole, plagioclase, monoclinic and rhombic pyroxenes can also be found in pumice as crystalline inclusions. Pumice is mainly used as lightweight aggregates for concretes, as well as a hydraulic additive to cements and lime [8–10, 1, 2].

Due to the heterogeneous composition of pumice, lightweight concrete as a building material has not been scientifically studied. The composition of such materials is not regulated at the level of state standards due to their different properties and composition. There are only recommendations - manufacturers independently determine the percentages of components, which do not correspond to the real results and do not reflect the real picture.

The work aims to investigate the composition and structure of pumice from different regions of Georgia and to study their influence on lightweight concrete's physical and chemical properties.

MATERIALS AND METHODS

Six samples of four different locations of Javakheti region of Georgia were studied:

- two samples of Khulgumo location of Ninotsminda Municipality - gray and reddish;
- one sample of Paravani location of Ninotsminda Municipality - reddish;
- two samples of Okami location of Akhalkalaki Municipality - gray and reddish;
- one sample of Modegham location of Borjomi Municipality – gray;

Chemical, X-ray diffraction, IR-spectroscopic, petrographic and granulometric analysis methods were used for the study.

X-ray diffraction analysis was carried out on a Dron-4 device (Russia). The X-ray diffractometer was connected to a personal computer via the USB port multimeter AX-18B, which allows the processing of experimental data in Excel format;

Infrared spectrometric analysis was carried out on an Agilent Cary 630 FTIR Spectrometer in the range of 350–5000 cm^{-1} (USA);

Chemical analysis was carried out on a Spectroscout XEP-04 (Germany).

RESULTS AND DISCUSSION

The results of Chemical Analysis of Pumice Samples. The results of the chemical analysis of the studied pumice samples are presented in Table 1. In terms of SiO_2 content, the samples have a medium acidic environment. It should be noted that they contain large amounts of iron, magnesium and calcium.

The results of petrographic analysis. Petrographic analysis of the samples showed that the gray sample of the Khulgumo location is a porous rock in the main amorphous mass of which the smallest plagioclase grains [9] (albite – $Na[AlSi_3O_8]$ and anorthite – Ca $[Al_2Si_2O_8]$) with pore size more than 2 mm are observed. The red Khulgumo sample is a hard porous rock with a pore size of 1–2 mm. Plagioclase grains (albite – $Na[AlSi_3O_8]$ and anorthite – Ca $[Al_2Si_2O_8]$) are mainly observed in the amorphous mass. The rock pores are filled with zeolite $M_{x/n}[Al_xSi_yO_{2(x+y)}]\cdot pH_2O$ by rather large porphyry grains over 1 mm in size. In some places, reddish-brown iron rust are observed [1].

The red sample of Paravani locality is also a hard porous rock the main mass of which is amorphous and has a reddish hue under the influence of iron rust. The smallest grains of plagioclase – Na $[AlSi_3O_8]$ and Ca $[Al_2Si_2O_8]$) – are occasionally observed in the mass. Relatively large porphyry grains of pyroxene $CaMg(S_{i2}O_6)$ or $CaFe(S_2O_6)$, plagioclase – $[Na(AlSi_3O_8]$ and amphibole – $Ca_2(Mg,Fe)_5\{S_{i4}O_{11}\}_2\{OH\}_2$ – over 1.5 mm in size are often found in the rock [1, 4].

The gray-colored sample of the Okami locality is a highly porous rock, the size of which is so large that most of the hewn sample (more than 80 %) falls on a porous area. The main amorphous mass is black, grayish areas are found in it (reddish are less common). No small plagioclase grains were observed here, which distinguishes this sample from other samples studied. Large porphyry segments of plagioclase larger than 2 mm are often found in the rock. The red porous rock of the same locality also has large pores. The main amorphous mass is black, reddish areas are found in it. Here, as in the black samples of the same locality, there are no small plagioclase grains. Instead, the rock contains large plagioclase porphyry grains over 3 mm in size (Fig. 1).

Table 1. Chemical Analysis of Pumice Samples, %

Material name, Quarry	Loss when heated	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	MnO	Na_2O	K_2O	SO_3	Total
Grey pumice, Khulgumo	1.36	59.75	16.88	6.5	6.27	3.48	0.02	3.14	1.83	0.00	99.20
Red pumice, Khulgumo	0.82	58.38	16.88	7.1	6.46	3.98	0.00	3.51	1.90	0.00	99.06
Red pumice, Paravani	1.83	58.86	17.00	6.3	6.07	3.66	0.01	3.33	2.22	0.01	99.33
Grey pumice, Okami	3.85	55.25	15.58	9.4	6.71	4.20	0.01	2.55	1.35	0.01	98.94
Red pumice, Okami	0.84	53.86	17.07	9.3	7.48	3.94	0.05	3.87	1.56	0.10	98.04
Grey pumice, Modegham	1.81	55.78	15.94	9.4	7.04	3.72	0.05	2.91	1.50	0.01	98.16

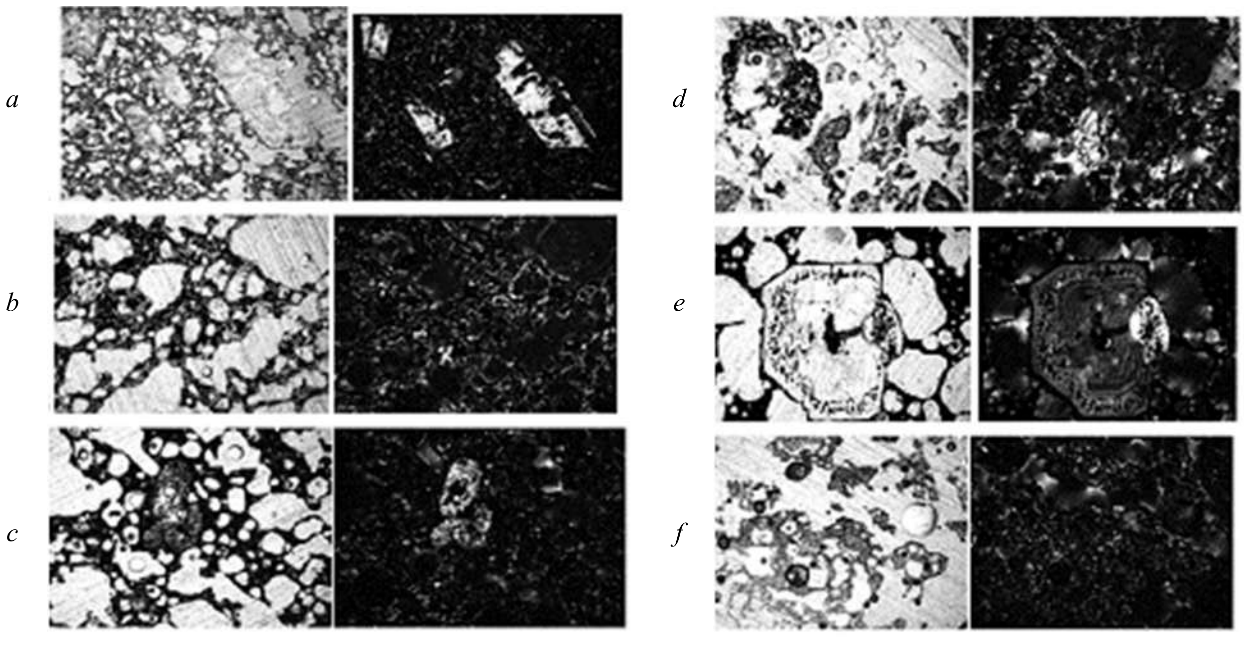

Fig. 1. Petrographic section of pumice of the: *a* – Khulgumo location grey pumice; *b* – Khulgumo location red pumice; *c* – Paravani location red pumice; *d* – Okami location red pumice; *e* – Okami location gray pumice; *f* – Modegham location grey pumice

The gray porous sample of Modeghami location is constructed from highly chlorinated $(Mg,Fe)Al(AlS_{13}0_{10})(OH)_8$ volcanic glass. Small grains of plagioclase and porphyry segments of the same mineral are developed in the main amorphous mass. Plagioclase is rarely observed in the amorphous mass. Thus, the mineralogical composition of the examined samples is similar, although there are differences as well. Interestingly, the porosity of the samples is significantly different from each other, so the pumice studied has a wide range of applications depending on what properties of the concrete we want to obtain.

The results of both X-ray diffractometric analysis and IR-spectroscopy. X-ray diffraction analysis (XRD analysis) of pumice samples was performed for structural as well as mineralogical studies (Fig. 2). XRD analysis showed that all pumice samples contained a large amount of amorphous phase, quartz (SiO_2); both types of feldspar – potassium-sodium-containing (alkaline) and sodium-calcium- containing (so-called plagioclase subgroup) were observed in all samples. In small amount samples also contained mica.

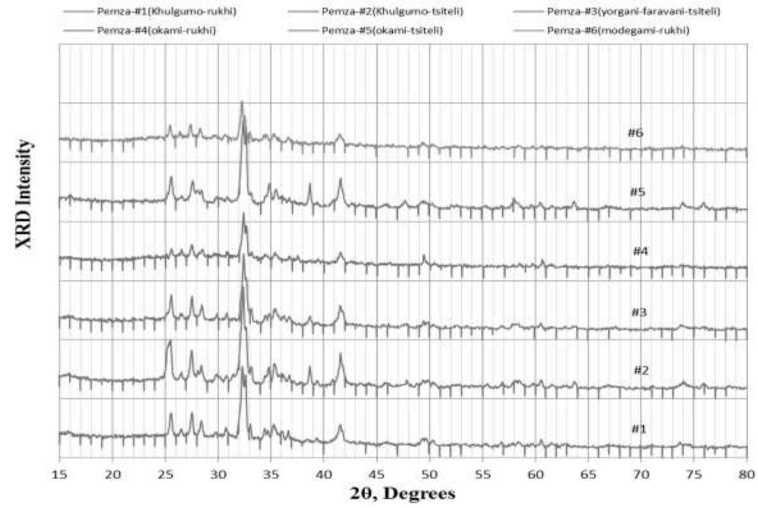

Fig. 2. X-ray Diffractograms of pumice samples (with cobalt tube)

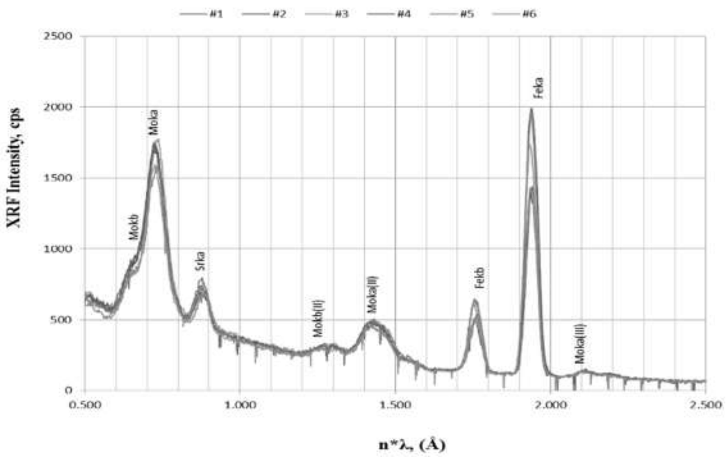

Fig. 3. X-ray Diffractograms of pumice samples

X-ray fluorescence analysis was performed to detect iron atoms in the crystallographic plane. During the experiment, the solid content of iron nanoparticles in pumice samples was found, as well as the presence of strontium nanoparticles in all samples, which was not detected by chemical analysis (Figs. 2, 3).

IR-spectral analysis was performed in the middle and far regions of IR-spectrum (350–5007 cm^{-1}). Table 2 shows the IR-spectra of the test samples. Studies have shown that pumice is a mixture of silicates and aluminosilicates of various structures [11, 12]. Both amorphous and layered silicates and aluminosilicates are present here [12]. In addition, there are quite large amounts of iron, magnesium, calcium, sodium and potassium cations in the samples [2], so the spectra are very diverse.

Table 2. Vibrational assignment of the IR-spectrum of studied samples

Vibrational assignment	Pumice samples					
	Grey pumice, Khulgumo	Red pumice, Khulgumo	Red pumice, Paravani	Grey pumice, Okami	Red pumice, Okami	Grey pumice, Modegham
σ Si─O, δ Si─O─Si	465, –	431, 470	441, 466	402, 465	433, 468	410, 466
Mg-O-Si, Fe-O-Si, Na-O-Si, δ Si-O, δ O-Si-O	543, 580, 629	541, 582, 632	543, 570, 627	537, 577, –	541, 582, 630	541, 574, –
ν Si─O─Si	779	789	778	745	770	–
ν Si-O, ν Si-O-Si(Al)	1028, 1089	1037, 1094	1045, 1077	1035	1018, 1093	1043, 1095
δ H─O─H	1647	1651	1637	1654	1654	1651
ν OH^-	3503	3501	3526	3503	3502	3538

Table 3. Physical characteristics of porous materials

Material name, Quarry	Moisture, %	Bulk mass kg/m^3	Tightened bulk mass kg/m^3	Strength, MPa	
				28 days later	90 days later
Grey pumice, Khulgumo	1.4	1077	1232	26.31	33.32
Red pumice, Khulgumo	2.2	993	1182	21.05	24.96
Red pumice, Paravani	2.7	1078	1233	14.03	17.96
Grey pumice, Okami	9.0	590	723	5.77	8.87
Red pumice, Okami	2.1	775	937	10.66	13.66
Grey pumice, Modegham	3.7	765	902	8.16	13.18

It should be noted that the vibrational frequency of the Si-O-Me bond of Mg- and Fe-substituted pumice coincide in the range of 530–630 cm^{-1} [2, 12], so it is difficult to assign particular bands in this region. Here, the band frequencies and their intensities vary depending on the content of two- and trivalent iron cations [11]. It should be noted that the overall picture of the spectrum of all investigated samples is similar, although the band intensities and frequencies are different due to different chemical and mineralogical composition of the minerals, which is caused by the different amounts of cations contained in the minerals.

The granulometric composition of the studied porous materials as well as the moisture, density and bulk mass were determined. The results are presented in the Table 3.

CONCLUSION

During the study, it was found that the tested pumice samples have a medium acidity environment (content of SiO_2 is 54–65 %), although they differ both in chemical and mineralogical composition and in pore size. Both their bulk and compacted volume weight are different.

The pumice samples studied differ in both chemical composition and porosity. This can be clearly seen both by the results of research by physical and chemical methods, and by the results of geological and mechanical studies.

Of particular interest are pumices with low density and volume mass (from Okami and Modegami deposits). Lightweight concrete made from these pumices are characterized by good thermal and noise insulation. Concretes made from Hulgumo and Farawani pumice are characterized by relatively high strength.

The diverse composition of metal cations makes the pumice surface active enough to react with binders, and this helps to increase the compaction of lightweight concrete.

The experiment showed that according to its results, it is possible to select and recommend porous materials of different composition and volume to obtain structural lightweight concretes of appropriate strength and weight.

Перспективи використання пемзи з Грузії в легких бетонах

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Легкий бетон – будівельний матеріал, густина якого не перевищує 2000 кг/м^3. Його структура визначається структурою використовуваних компонентів і методами виготовлення. Перевагами цих будматеріалів є їхня низька густина, хороша теплоізоляція, морозостійкість, висока термостійкість, зручність використання блоків, що обумовлено їхніми великими розмірами і малою вагою; також важливий їхній широкий асортимент, що дозволяє підібрати оптимальний склад матеріалу, відповідний умовам експлуатації. У виробництві легкого бетону пемза, поряд із в'яжучими, є одним з основних компонентів його складу. Ці мінерали пінисті, мають малу об'ємну вагу, високу пористість і високу в'язкість. Усі ці властивості роблять їх цінною мінеральною сировиною, яка в основному використовується як добавки для легких бетонів і гідравлічних цементів. Пемза поширена в Грузії (понад 35 млн м^3). Перспективи використання цих мінералів великі, тому вивчення їхніх фізико-хімічних властивостей є актуальним і обов'язковим. Було вивчено шість зразків пемзи з чотирьох різних місць у регіоні Джавахетія в Грузії. Для досліджень використовували хімічний, рентгенівський дифрактометричний, інфрачервоний спектроскопічний, петрографічний, гранулометричний методи. Визначено хімічний і мінералогічний склад досліджуваних проб, особливості їхньої будови, а також об'ємну масу сипучих і ущільнених проб та їхній гранулометричний склад. Шлаки з найкращими властивостями будуть рекомендовані як добавки для використання у виробництві легких бетонів.

***Ключові слова**: вулканічне скло, пемза, легкий бетон, пористі матеріали*

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