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The Impact of Finely Dispersed Micro Filling Materials of Volcanic Ash on the Concrete Properties

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ABSTRACT

The paper presents practice of volcanogenic mineral supplements using for obtaining composite bonding material. Volcanic rocks are formed as a result of an enormous number ejection of melted rock debris and extremely small lava flour particles. Larger particles are dropped on a slope of volcano, and the smallest ones are cooled by air and falls on earth as volcanic ash. On the phase constitution it represents the mixture of partly amorphized glass, silicate and aluminum silicate. It was demonstrated that the sizes of volcanic particles are very small and have vesicular structure so the density is lower as for rock material. This property enables arising to the atmosphere and spreading far through air. They do not dissolve in water forming suspension and mud when wet, which turn into hard concrete after drying. Elementary composition of ash is related to magma composition of which it is formed. Given the fact that the majority of elements found in magma are silicone dioxide and oxygen, generally ash consists of silicon particles. The ash of basaltic ejection contains 45-55% of silicone dioxide rich in iron and magnesium. With explosive rhyolitic ejection volcanoes eject ash with high-silica content (more than 69%). After mechanical activation the volcanic ash was used as an element of composite bonding material. The paper presents the volcanic ash research and describes the test results of composite bonding material for obtaining high-strength concrete. It was demonstrated that using of such materials will bring new class of substances named superplastic bioconcrete, which can be used not only in the construction industry but also in remastering and renovation of premises that are highly depressive nowadays. There are represented ways how to optimize situation.

KEYWORDS
Volcanic ash; mineral supplement; finely dispersed micro filling material; superplasticizer; structure formation; low water content; and mechanical activation.

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Introduction

Full savings of cement in providing construction high-quality is one of the most important problem of concrete producing (Hossain, 2006). To date concrete technology has a wide range of techniques that under particular conditions provide reducing of cement specific charge without compromising of concrete technical properties. In recent years to that end, it was proposed to use in plasticized concrete mixture active mineral fillers (Al-Zboon et al., 2016; Bebbington & Zitikis, 2016; Blake et al., 2016; Bonadonna et al., 2016; Cai et al., 2016; Cai & Zhao, 2016). The idea of charging of disperse mineral fillers to concrete formation is relevant to

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papers of L.I. Dvorkin et al. (1991), C-A. Yu. Murtazaev, M.Sh. Salamanova, W.V. Vataev (2014) and others.

In concrete technology the mineral fillers traditionally regarded as elements which were input for preventing cement overspend for low-grade concrete. Using of superplasticizer supplements made possible to increase significantly the effect achieved under the process of fillers loading (Chang et al., 2016; Columbu et al., 2016; Costa et al., 2016; Kurt et al., 2016; Mota-López et al., 2016). Finely dispersed active mineral fillers in plasticized concrete mixture with low water content affect the condition of structure formation and synthesis of concrete properties. As a result, new area in concrete technology is appeared, realizing significant reserves of cement savings, hardening, and improving of other concrete properties (Dvorkin et al., 1991; Bazhenov et al., 2006; Salamanova & Ismailova, 2014; Opoczky, 1993; Murtazaev et al., 2015a; 2015b).

Materials and methods

As a result, experimental work aimed at research of active volcanogenic mineral supplement are held at the technical research center of common use "Modern construction materials and technologies" of Grozny National Oil Technical University named after M.D. Millionshchikov.

Volcanic rocks in Russia are located in the region near the Chechen Republic – Kabardino Balkaria, and they are unique raw material for the construction industry. Silvan and pastoral ranges consist of tuff thick mass, pumice and ash. The best known mine fields of volcanic rock are Zaiukov (tuff), Kamensk (tuff), Kurkuzhynsk (tuff, ash), Lechinkaev (lining tuff), Nalchinksk (tuff, ash, pumice), Kenzhensk (ash, volcanic tuff), Belorechensk (ash).

The rocks were formed as a result of volcanic eruption, an enormous number of melted volcanic rock debris of different size and extremely small lava flour particles are ejected from their craters besides extrusive lava. Larger particles are dropped on a slope of volcano, and the smallest ones are cooled by air and falls on earth as volcanic ash (Tusa & Langer, 2016; Wang et al., 2016; Zakharikhina et al., 2016). If volcanic ash retains earthy loose structure in these conditions then it is often named as ash (puzzolana); if it turns into pore lithoidal rock as a result of secondary process - volcanic tuff (Kolbasov et al., 1987).

By elementary composition the volcanogenic supplements largely consist of silicon earth and aluminum earth (70-90%), there are CaO and MgO in small amounts (2-4%), alkali Na_2O and K_2O (3-8%), and hydrate water that removed on ignition (5-10%). On the phase constitution it represents the mixture of partly amorphized glass (50-80%), silicate and aluminum silicate, as well as solid state hydrates. Generally they contain different additional materials (Kolbasov et al., 1987).

Volcanic ashes are found in the form of flour particles mixture (less than 0, 15 мм) in amounts of 60-65% and more, as well as pumiceous particles of sand and break stone (0, 15-70 mm) of medium hardness. The density of volcanic rock ranges 2, 3-2, 6 h/cm^3. Specific weight of tuffs (in pieces) is averagely 1200-1500, trass – 1800-2000, and pumice about 500 kg/m^3 (Murtazaev et al., 2014).

Results and discussion

In the Kabardino-Balkar Republic the volcanic ash is used as small fillers for expanded-clay concrete, for solid and porous structural insulating concrete of ash В3, 5-В7, 5 with average density 1200-1550 kg/m^3 and for plaster mortar. This publication illustrates the result of experimental work aimed at research of volcanic

ash for development of composite bonding material and obtaining effective high-strength concrete on their basis. Volcanic ash, used as micro filling materials taken together with effective superplasticizer, serves as structure-forming supplement for obtaining high-strength concrete.

As part of the study in order to solve the issue the qualitative materials were used as source materials. Portland cement with constant elementary and mineral composition CEM I 42H of Chiri-Jurtovsk cement factory was used at the heart of bonding material. General properties and chemical analysis in the tables 1 and 2 below.

Table 1. General properties Chiri-Jurtovsk cement

		Standard consistency %	Density, kg/m^3	Setting time, hour - minute		Activity, MPa, 28 days	
Manufacturing factory and brand	Specific surface area m^2/kg			Start	Finish	Pressure	Bend
Chiri-Jurtovsk CEM I 42H	330	25	3100	2-15	3-40	52,6	6,2

The local filler was used as large and small aggregate: break stone of Argunsk fracture mine field 10-20 mm and sand of Chervlensk mine field МҚ=1,8. Sampling for the researches was carried out as per GOST30515, GOST 8269 and GOST 8735.

Table 2. Elementary composition of portland cement, %

Name	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	SO_3	TiO_2	K_2O	Na_2O
Chiri-Jurtovsk	17,45	3.88	3,72	1,12	71,56	0,76	0,33	1,07	0,11

As mentioned previously, the volcanic ash of the Kabardino-Balkar Republic (figure 1) which was exposed to mechanical activation in the roller sampler pulverizer during 30 minutes and has specific surface area 850 kg/m^2 was used as micro filling material. Aimed milling time was set after experimental researches.

Examining of the volcanic ash particles with scanning electron microscope (figure 2) illustrates that there is roughness with different shapes and sizes on the flake surface, and independent layers have closed porosity, therefore, the surface of ash particles is an inoculating of genesis and crystal neogenesis growth. The volcanic ash consists of the particles of amorphized silicon earth $SiO_2 \cdot 2H_2O$ which readily reacts with calcium hydroxide released during hydration of cement in so doing increasing of number of hydrated silicate type CSH (Maki et al., 1993; Kakali & Tsivilis, 1993).

Chemical analysis of the volcanic ash particles in Table 3 below.

Table 3. Elementary composition of the volcanic ash, %

MgO	Al_2O3	SiO_2	K_2O	CaO	Fe_2O_3	Na_2O	CuO	Percentages of other impurities
0,20	13,57	73,67	6,00	1,79	1,52	2,85	0,40	-

Figure 1. Kenzhen volcanic ash open cast mine in the Kabardino-Balkar Republic

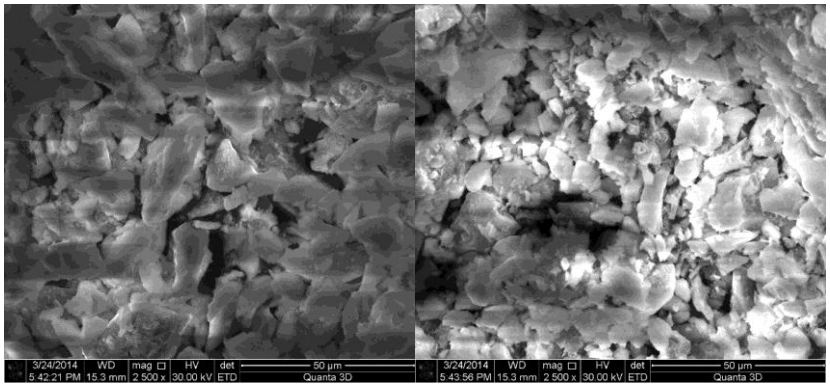

Figure 2. Micrographics of the volcanic ash particles of the Kabardino-Balkar Republic

Super-effective plasticizer SikaSikaViscoCrete 5-600 SK was used to obtain concrete with stress-related properties. This additive with polycarboxylate esters base has supreme plasticizing and hydro-reducing effects. Experimental composition and general properties of the high strength concrete with using of micro filling material from volcanic ash and superplasticizer SikaViscoCrete 5-600 SK in the table 4 below.

Table 4. Composition and properties of the high strength concrete

Cement-water factor	Charge, kg/1m^3					Additive charge SikaViscoCrete, %	Water uptake, %	Concrete density, кг/мм^3	Compressive strengths mature, days MPa	
	C	VA	S	B.s.	W				7	28
0,45	450	-	560	1120	202	-	3,7	2330	23,1	32,4
0,35	430	80	540	1120	150	1,3	3,5	2320	40,6	65,2
0,33	430	100	520	1120	142	1,5	2,8	2312	39,1	65,9
0,35	430	120	540	1120	150	1,4	2,1	2360	46,9	66,7

Notes: C – cement, VA – volcanic ash, S – sand, B.s. – break-stone, W-water

Conclusion

According to the results of undertaken study the effective influence of finely disperse volcanic ash along with superplasticizer SikaViscoCrete 5-600 SK on structure formation of concrete. In these conditions concrete stress-related properties are significantly improved as well as cement specific charge is reduced.

The explored compositions of concrete mixtures with using of micro filling materials and modern chemical additives provide producing of durable concrete for high demands of strengths, waterproofing, cold-resisting and crack resistance.

Disclosure statement

No potential conflict of interest was reported by the authors.

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