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Fine-Grained Structure Concretes on the Basis of Composite Gypsum-Containing Binding Agents with a Man Made Filler

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ABSTRACT

The article is devoted to an actual problem of increase of efficiency and cost reduction of fine-grain concrete in the production of small-piece wall products with the complex use of man-made materials in the form of bottom-ash mixtures of CHP. The article presents the results of the study of bottom-ash mixtures and based on them composite gypsum binders (CGB) for fine-grained concretes. There were studied the microstructure and morphology of the floured ground mineral supplements of the bottom slag and fly ash, the prospect of these components using as a filler in the composition of CGB. There investigated properties of the fine-grained concrete and concrete mixes based on this CGB: remoulding effort, porosity, density, strength and stress-related properties. There were experimentally proved the effectiveness of the integrated use of local raw materials, including man-made, in the production of CGB and fine-grained concrete on its basis.

KEYWORDS
Man-made raw materials, city ecology, bottom-ash mixtures, bottom-ash mixtures fillers, composite gypsum binders, fine-grained concrete, small-piece wall products, environmental and economic effects

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Introduction

At the present time, dynamically increasing rate of construction in a number of regions, including in the Chechen Republic, dictate a significant increase in production of high quality building composite materials, manufacturing and processing of which requires the least possible energy and investment. The need to develop and implement effective production, including the so-called "green composites", is also dictated by modern requirements on resource and energy efficiency in construction and energy efficiency increase of building production.

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Some of such materials that meet the requirements of resource and energy efficiency in their manufacture, thermal protection and environmental safety are gypsum binders and products based on them, as the most effective in terms of energy intensity of production and the negative impact on the environment, and their hardening takes place rapidly without heat and humidity treatment (Murtazaev et al., 2015b).

The most promising solution of this problem, in accordance with modern international requirements of the "green construction" and "green composites" program, is the integrated use of affordable, low-cost, often unclaimed local raw materials, to which, in addition to natural resources, refer the secondary resources and man-made origin resources.

For the Chechen Republic, possessing the large reserves of natural raw materials for the production of cement, gypsum binders, fine-grained and coarse aggregate concretes, as well as the raw materials of man-made origin in the form of large-tonnage bottom-ash mixtures (BAM), concrete scrap and other waste of buildings and structures demolition, production of high quality building materials with complex use of local raw materials can make a significant contribution to the further formation of the construction industry and provision of environment protection (Alaskhanov, Murtazaev & Chernysheva, 2013).

In addition, currently in the region there is a need in many building materials, especially for wall construction. At the rational use of the existing mineral resource base on the basis of advanced technology, one can get a competitive construction products, equal to foreign analogues. This fully applies to the production of composite gypsum binders (CGB) filled with BAM and wall products on their basis, which allow to significantly reduce the shortage in building materials for the repair and restoration of old, destroyed buildings and construction of new facilities.

This scientific direction for the development of effective composite building materials with the use of secondary resources is very relevant to the whole country, as currently in the mining, metallurgical, chemical, wood, energy, building materials and other sectors of the Russian industry are generated more than 7 billion tones of waste per year. And only about 2 billion tons, or 28% of the total volume, are reclaimed. In connection with this, in the dumps and sludge ponds of the country has accumulated more than 80 billion tons of only solid waste. To store this waste are annually alienated about 10 thousand hectares of land suitable for agriculture (Dvorkin & Dvorkin, 2007).

Materials and Methods

Perspective direction of building materials industry development is the development of non-waste technology for the production of construction composites that are made on the basis of gypsum binders that meet all modern requirements on: fire resistance, sound absorption, environmental assessment standards of the International Standards that take into account all stages of the product life cycle, staring from extraction of raw materials and to disposal, on hygienic and safety requirements for the public health (Gusev, Dement'ev & Mirotvortsev, 1999; Ursu & Dorozhkin, 2007; Murtazaev et al., 2015a; 2015b; Wolicka, 2008). Derivatization of waterproof rapid-hardening gypsum-containing binder with complex use of man-made raw materials will significantly increase forms turnover, production efficiency of products based on them, simplify the technology, allowing to get rid of the thermal treatment of products, and to reduce the cost of the finished product.

In the solution of the problem of gypsum waterproofing and mechanical strength increase were involved and now are involved many Russian and foreign researchers:

P.P. Bednikov (1951), A.V. Volzhensky (1986), A.V. Ferronskaya (2004), V.F. Korovyakov (2005; 2013a; 2013b) and others. Application field of gypsum materials and products is limited to a relative humidity of rooms up to 60-75%. Therefore, many researchers are working on gypsum binders and gypsum products waterproofing (Alhaj, 2010; Strokova et al., 2013).

According to P.P. Bednikov (1951), the main cause of low water resistance of gypsum products is the relatively high solubility of gypsum component, constituting 2.04 g / l of CaSO4 at 20 ° C. When watering in the pores of the products due to dihydrate crystals dissipation is formed saturated calcium sulfate solution, whereby the bond between the crystals is diminished, and strength of products is reduced.

V.K. Shukla et al. (2005) believe that the reason for the hardened gypsum binder strength reduction at watering is the adsorption of moisture by inner surfaces of the micro cracks and originating at that wedging action of water films, resulting in the individual crystal structures micro elements disconnection. At that the adsorption effect is exacerbated by gypsum materials porosity.

Low water resistance of gypsum binder dependent on the high solubility of calcium sulfate dihydrate, its high permeability and wedging action of water molecules at the penetration into the intercrystalline cavities. The structure of the hardened gypsum binder is characterized by highly interconnected porosity with a pore size in the range of 1.5-3.0 microns, elongated calcium sulphate dihydrate crystals that have a point interconnections, having a tendency to disruption at low strains. In addition, calcium sulfate dihydrate is characterized by a large enough amount of interplanar (intercrystalline) spaces (cavities), to which the water penetrates, weakening the coupling and dissolving the gypsum (Ferronskaya, 2004).

There are numerous ways to improve the gypsum water resistance: improving of gypsum water resistance is achieved through reduction of calcium sulfate water solubility, gypsum mass impaction, impregnation with substances, preventing penetration of moisture.

In recent years, some researchers are attracted by the hypothesis that the interaction of various binders with water, especially polymineral, in real conditions takes place simultaneously according to mixed pattern - with dissolution of the part of the substance in water, following hydration and transition into the sediment of hydrate, and also topochemically - with direct hydration to the solid phase.

Now it is proved that one of the main ways to improve gypsum binder waterproofing is the introduction of substances into it, which enter into chemical reaction with it forming water-resistant and hydraulic products both in the result of chemical reaction with the gypsum binder, and own hydration. Such materials are Portland cement, and ground granulated blast furnace slag, the use of which is noted in article V.S. Lesovik, M.S. Ageeva & A.V. Ivanov (2011). The use of Portland cement as an additive to gypsum often led to conflicting results. In some cases, increased water resistance and increased strength was achieved in the initial period of hardening, in other cases with an increase in the water resistance the samples, having at the beginning sufficient mechanical strength, destroyed in 30-40 days.

One of the ways of gypsum binders water resistance increase is the creation of gypsum-cement - pozzolan binders (GCPV), as well as the development of GCPV technology.

The most stable and effective compositions are the new generation compositions - the composite gypsum binders of low water demand (CGB), which are proposed and thoroughly studied in Moscow Civil Engineering Institute named after V.V Kuibyshev (now MCEU) and other organizations by A.V. Volzhensky (1986), A.V. Ferronskaya (2004), V.F. Korovyakov (2005; 2013a; 2013b) and others on the basis of applications of nanotechnology advances and physical and chemical mechanics in the field of building materials, including binders. These compositions consist of a gypsum binder, Portland cement and proper amount of pozzolanic hydraulic additives containing silica in active form and capable to harden without destructive deformations in a moist environment and aqueous environments at the same setting rate as the hemihydrate gypsum binder. Unlike Portland cement, the products of these binders, in many cases, do not require heat and humidity treatment as in 2-4 hours after production gain up to 30-40% of the final strength (Ferronskaya, Korovyakov & Kaleev, 1988).

V.F. Korovyakov (2005) has developed scientific concept, according to which the CGB should be a homogeneous mixture of dispersed components, one of which should serve as a controlled early setting fast curing (it can be one or a combination of modifications of gypsum binders). The other or others - should ensure binder hydraulic properties and further increase in strength due to the formation of a new type of structure, helping to improve the durability and other properties of the resulting stone (in their capacity may be used activated Portland cement or lime together with silica mineral components of optimal dispersity). Third - modifying agents - are designed to dramatically reduce the binder water demand, contributing to its better and faster hydration, provision of dislocations approach, thereby increasing the number of contacts between particles, control of other properties in the right direction (for this purpose can be used plasticizers, set and curing regulators, polymer additives) (Hanna, Abu-Ayana & Ahmed, 2000).

On the basis of modern concepts of gypsum cement, siliceous systems hardening mechanism, one may state that in order to ensure their durability it is necessary to comply with the following conditions: to ensure binding of the majority of the aluminates with gypsum with formation of ettringite during the initial period of hardening of the system with simulaneous increase in the degree of hydration of Portland cement, for example, with the help of mechanical-chemical activation (Kaziliunas & Bacauskien, 2007); maintaining of calcium hydroxide concentration at the required level during hardening to ensure conditions for formation of various hydrated newgrowths, including low-basic calcium aluminate hydrates. For this siliceous additive amount should correspond to the amount of Portland cement and its mineral composition, and calcium hydroxide binding with additive silica should take place during both the initial period of structure formation and prolonged hardening. For this purpose can be used both high-level waste of various production (microsilica, fly ash, slag, etc.) and low active waste (ceramic dust, fine silica sand, glass scrap, etc.) in combination with the active waste (Belov & Smirnov, 2009; Kolesnikova, 2002).

Another fairly well-known water-resistant gypsum binder is gypsum-lime-slag binder (GLSB), developed in the Urals Polytechnic Institute and implemented in the Krasnoufimsk factory of building materials. Designed binders, unlike non-water-resistant gypsum binders, have universal properties, which are manifested in the ability to hydraulic hardening, less prone to plastic deformation and sufficient durability (Burnett & Elzerman, 2001; Perianez, 2005; Pereira, 2003).

But, despite the high technical and economic efficiency of building materials such binders and their use in construction at the moment is not sufficient. Therefore, improvement of efficiency of gypsum binders and concretes on their basis, aimed at perfection and improving of technological, functional, operational properties, expansion of the scope of gypsum binders is a burning problem.

Thus, the analysis of domestic and foreign applications of gypsum-containing composites in construction showed that the materials and products on their basis to the greatest extent meet the requirements of modern architecture and construction practice. The decisive factor is the quality and cost of the material, the speed of construction of facilities, expansion of the architectural and engineering solutions based on the use of quick-hardening concrete with improved strength and deformation characteristics.

For a number of regions of the country, including the Chechen Republic, the widespread use of gypsum binders in the construction and decoration of buildings and structures is especially important: there are large reserves of explored deposits of gypsum; the use of materials based on gypsum binders creates a more comfortable environment for human habitation in the room in different climatic zones with a large range of variation of temperature and humidity parameters; production time with the use of concrete and mortar based on gypsum binders is several times less than with similar materials based on Portland cement, etc.

Therefore, the most important area of research in building materials science is the improvement of production technology of gypsum-containing composites, improvement of their performance and operational characteristics that will contribute to the development of "green building" and the production of "green" high-performance construction materials.

Results and Discussion

In this regard, in the Scientific and Technical Centers for collective use of the Grozny State Oil Technical University named after academician M.D. Millionshtchikov and Belgorod State Technological University named after V.G. Shukhov there are carried out comprehensive studies to solve the actual problem for the development of the formulation of the composite gypsum-containing binders and concrete on its basis with the use of man-made and natural substandard raw materials.

To study and analyze the properties of the materials (fly ash and slag) and gypsum-containing composites produced on their basis, as an instrumental methods of researches were - XRF, SEM, SORBI-M (The device is designed for measuring of specific surface area of dispersed and porous materials), and standard methods for determining the properties of raw materials, mixtures, hardened composites on the basis of CGB.

To investigate the effect of a composite gypsum binder, the type of active mineral additives, chemical additives on the properties of concrete mixtures and hardened gypsum-containing composites were used the complex methods of research, regulated by state standards.

Research methods, used in the framework of research on the scientific work, are based on the known positions of the theory of hardening of clinker minerals with fillers of different composition, in particular, of bottom-ash mixtures (BAM), mathematical logic, technology of composite materials, theory of process and production automation and control.

According to the results of preliminary tests in view of the non-homogeneous composition and features of processing of man-made raw materials, it was found that one of the ways of rational use of secondary resources is to introduce them into the fine-grained concrete as a fine filler in conjunction with chemical modifiers.

As starting materials for the production of fine-grained concrete for small sized wall products were used BAMs as an active mineral additive, Portland cement CEM I 42,5N from Chiri-Yurt cement factory, chemical additives superplasticizer Polyplast SP-

1 and citric acid, gypsum binder of the brand-modification G5B II of Astrakhan gypsum plant, as well as sands: slag - of Grozny TPP heaps; quartz - of Chervlensky field.

Research of BAM properties (Table 1) entered into gypsum-cement composition for controlling the hardening process and contributing to a change in the final properties of the materials, showed that their hydraulic activity is the most important feature promoting the possibility of their use in the binders and concretes on their basis. Thus the increase in BAM specific surface area increases the reactivity of its minerals, contributing to the elimination of conditions of formation and accumulation of ettringite due to binding of calcium hydroxide with activated silica and reduction of the amount of aluminate components due to rapid hydration of Portland cement. This causes an increase in strength and durability of the formed structure of hardened gypsum-containing binders with bottom-ash filler and concrete on their basis.

Table 1. Indexes of floured mineral admixtures properties

Index	Floured mineral admixture of	
	fly ash	slag
Specific surface area, m2/kg	600-690	450-500
Voids volume at R<19,4 nm, cm3/kg	18	3
Milling time, min	5-10	5-10

It is found that the slag (fly ash) contains, % SiO_2 – 67,46 (52,44); Al_2O_3 – 15,05 (5,57); Fe_2O_3 – 2,65 (11,37); TiO_2 – 0,36 (0,28); MgO – 0,54 (2,35); CaO – 5,45 (19,8); K_2O – 5,16 (2,02); Na_2O – 2,59 (0,86); SO_3 – 0,24 (1,28).

Analysis of the results of the chemical composition of the mineral additives of BAM shows that they contain SiO_2 and Al_2O_3 that at normal temperatures in particulate form are capable of binding calcium hydroxide to form insoluble compounds, i.e. have pozzolanic activity, and therefore, can be used in the production of CGB as active mineral additives.

It is also found that the composition of ash and slag products have firing clays: amorphized clay matter of metakaolinite type, amorphous SiO_2 and Al_2O_3, aluminosilicate glass (6).

More acidic mineral additive having a lime factor Ml <1, have higher activity, which can be judged by from the value of aluminate modulus p and the modulus of activity Ma(Table 2). BAM hydraulic activity increases with the value of these modulus, while the higher the activity module, the faster hardens BAM in the crushed state.

Obtained results are confirmed by experimental data of the kinetics of emission of heat of mineral additives. Kinetics of heat emission of fly ash and slag was studied from the moment of mixing with the water of mixing. In the study was applied the differential quasi-isothermal calorimeter with computer processing (Fig. 1).

Table 2. A comparison of the CHP BAM characteristics

Module name	Index value, %	
	in slag	in fly ash
Aluminate module, p = Al_2O_3 / Fe_2O_3	5.68	0.50
Lime factor $\frac{Ml = CaO + MgO}{SiO_2 + Al_2O_3}$	0.07	0.38
Activity module, Ma = Al_2O_3 / SiO_2	0.22	0.11

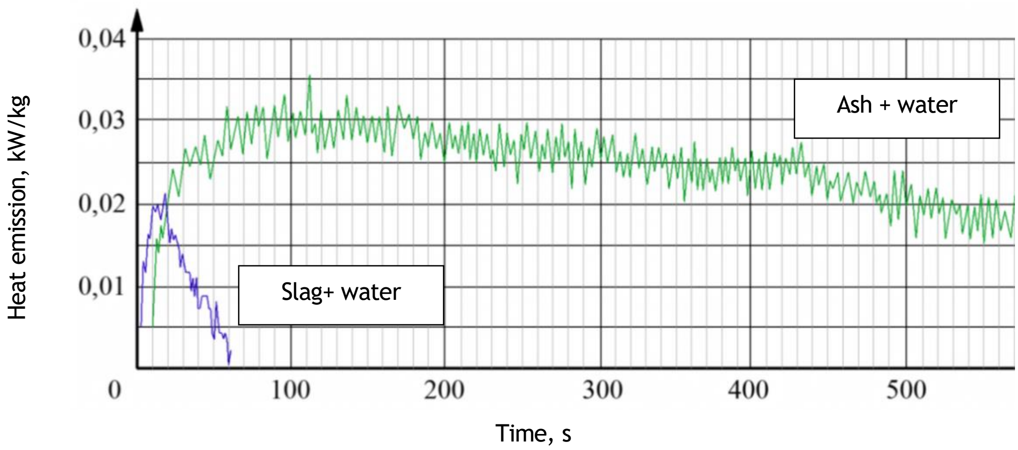

Figure 1. System heat pattern: a) ash + water; b) slag + water

It is found that the heat emission of the fly ash and slag differs in intensity and duration. After 100 seconds after contact with water, heat release rate of the fly ash reaches a maximum value - 0.03 kW / kg, and is characterized by lengthiness and delayed start of reaction of interaction with water (after 10 seconds). Slag significantly faster exhibits capacity of reaction (after 1-2 s), and after 10-15 s its heat emission reaches its maximum value - 0.02 kW / kg. Feature of given heat patterns is that the intensity of the heat emission residual level in the induction period in 200-500 s after mixing with water in fly ash is reduced by 25% only (up to 0.02 units.), while for the slag dramatic drop is observed in 15 -20 seconds and heat emission is almost completed after 50 seconds. This phenomenon can be explained by the fact that in an aqueous environment on the surface of the slag grains there is a large number of active centers of various nature, acting as a finished substrate for formation of hydrated compounds buds.

Analysis of the microstructure and morphology of fine mineral additives of fly ash and slag of Grozny THP showed that their particle shape differs depending on the size. Slag particles are composed mainly of dense glossy particles of different size, cubic and rounded shape, having a layered structure (Fig. 2a).

Most of the fly ash consists of porous glossy particles of various size of laminar, irregular and angular shape. The distinguishing feature is the presence in a mixture of porous, relatively large particles with a concave surface, as well as small particles of flocculated structure (Fig. 2b).

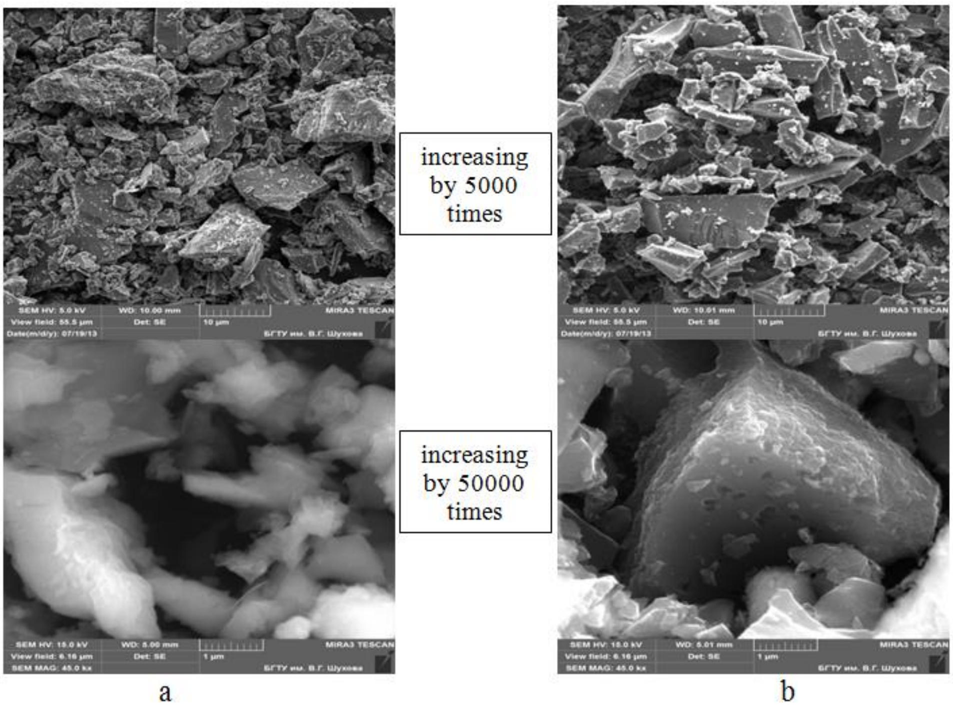

Figure 2. The microstructure and morphology of the fine ground slag mineral additives (a) and fly ash (b).

It is also necessary to note that the mineralogical composition of the fly ash will vary depending on the grade, dispersion of the pulverized coal, burning mode and other factors.

The crystalline component of THP fly ash, as shown by the results of XRF, consists of two modifications of quartz, magnetite of Fe3O4, CaCO3 calcite and calcium-glandular silicate CaFeSi2O6.

The slag is mainly (up to 95%) contains the glass phase due to the increased duration of slag staying in the high temperature zone. The crystalline phase is represented by albite, NaAl-silicates and Al-silicates, several different modifications of quartz (SiO2), which differ from the natural modifications by the crystal lattice parameters, due to its man-made origin.

Since the durability of gypsum cement systems (gypsum + cement + additive + water) depends on the right balance between the amounts of siliceous additives and Portland cement, the authors determined the influence of dispersive capacity and the ratio of components in CGB on the properties and structure of the hardened from it a stone (Gypsum + cement + additive).

Grain size curves of slag and fly ash with a specific surface area of 470 and 690 m2 / kg, respectively, showed that the primary particle size range of the fly ash, into which falls up to 90% of the material is limited to fractions (18,15-201 microns); and slag particles - to fractions (1,1-60,35 microns).

The effectiveness of action of the additives studied is evidenced by the reduction of calcium oxide concentration in the solution: for fly ash after 5 days up to 1,23-0,86 g / l, on the 7th day up to 1,18-0,84g / l, with obligatory ratio of mineral additives (A) and the cement (C) A / C = 1: 1.5; for slag after 5 days up to 0,22-0,14 g / l, on the 7th day up to 0,15-0,13 g / l, with the obligatory ratio A / C = 1: 0.5. The obtained ratios between A

/ C were the basis for calculation of the CGB recipe (9), which were adopted as follows. The two CGB formulations obtained the gypsum portion was 70% by weight, and the remaining 30% - Portland cement + mineral addition. In CGB, based on the slag mineral additive, the amount of the latter was 10%, in the CGB based on fly ash - 18% of the ash filler.

It was found that with a reduction in the concentration of calcium hydroxide fade conditions for the formation of highly basic calcium aluminate hydrates and ettringite. The cavities between crystals of calcium sulfate dihydrate are filled with tiny particles of tumors and ultrafine particles of Portland cement and active mineral additive that helps to increase contacts between the crystals and increase density, strength, water resistance and durability of the hardened binder, which is confirmed by comprehensive studies of its phase composition, hydration processes and stone structuring on CGB by electron microscopy and XRF methods.

To improve the physical and mechanical properties of stone on CGB to the mixing water was introduced hemihydrate of calcium sulfate $CaSO4 \cdot 0.5H2O$ in an amount providing obtaining o saturated solution - up to 7.1 g / l. With this it was found that at the introduction of $CaSO4 \cdot 0,5H2O$ the test mobility does not change, the strength of the hardened stone is increased by 18% after 2 h and 15% at 28 days age, and softening factor SF of the hardened composite constituted - 0,64-0, 69. It is important to stress that the introduction of $CaSO4 \cdot 0,5H2O$ increases not only the final strength of the hardened composite but also increases the setting time of the cement paste from 8 to 11-13 minutes. The mortar mix plasticity on the flow constituted 0.18 m at water/binder ratio W / Binder = 0,44-0,5.

As a result of the dissolution, hydrolysis and crystallization in CGB- water system, the main component of the porous electrolyte are associated CaSO4 molecules, changing concentration of which it is possible to adjust both the setting time and strength development of the hardened binder.

The authors also investigated the influence of chemical additives on CGB properties, as their role in fine multicomponent systems is very high (Table 3).

Table 3. Chemical additives impact on the CGB properties

№ s.n.	Type of additive	Additive content, % ppb mass	Flow, m	Setting time, min. - s		Compressive strength, MPa		
				start	finish	2 h	7 days	28 days
1	Without additive	–	0.120	8-00	11-00	3.4	13.4	14.1
2	Polyplast-LP-1	0.1	0.160	7-45	10-45	5.0	14.5	15.7
		0.3	0.180	7-30	10-30	4.4	13.9	14.7
		0.5	0.220	7-15	10-15	4.2	13.4	13.9
3	Citric acid	0.03	0.160	18-45	25-15	4.8	9.2	10.4
		0.05	0.162	24-30	28-30	4.9	9.7	11.4
		0.07	0.162	29-30	34-30	5.0	10.2	11.9
4	Citric acid + Polyplast LP-1	0,05 + 0,3	0.265	30-00	35-15	4.3	13.2	13.8

Binders fine grinding leads to an increase in their water demand, to flocculation of the particles while mixing with water, resulting in a significant amount of not hydrated grains. To reduce the water demand of CGB was used superplasticizer Polyplast SP-1, capable to disperse the solid phase particles, forming on them the solvation shells, for regulation of binder setting time - citric acid, as well as complex chemical additive (CCA). The plasticizing effect of surfactants was determined by the paste consistency with a constant V / Binder ratio. The additives were fed into together with the mixing water. The effectiveness of application of superplasticizer Polyplast-SP-1 (0.1-0.5%) is confirmed by the increase in the mixture mobility (from 0.12 to 0.22 m), of citric acid - by delay in time of initial setting from 18-45 to 29-30 minutes.

Developed CCA (citric acid + Polyplast SP-1) allows adjusting the beginning of setting up to 30 minutes and CGB hardening rate.

To create a small sized wall materials were selected formulations of fine concrete from harsh and easily workable mixes based on developed CGB on fly ash and slag as active mineral additives (Figure 3.), in weight ratios of 1: 1, 1: 2, 1: 3 (CGB: filler).

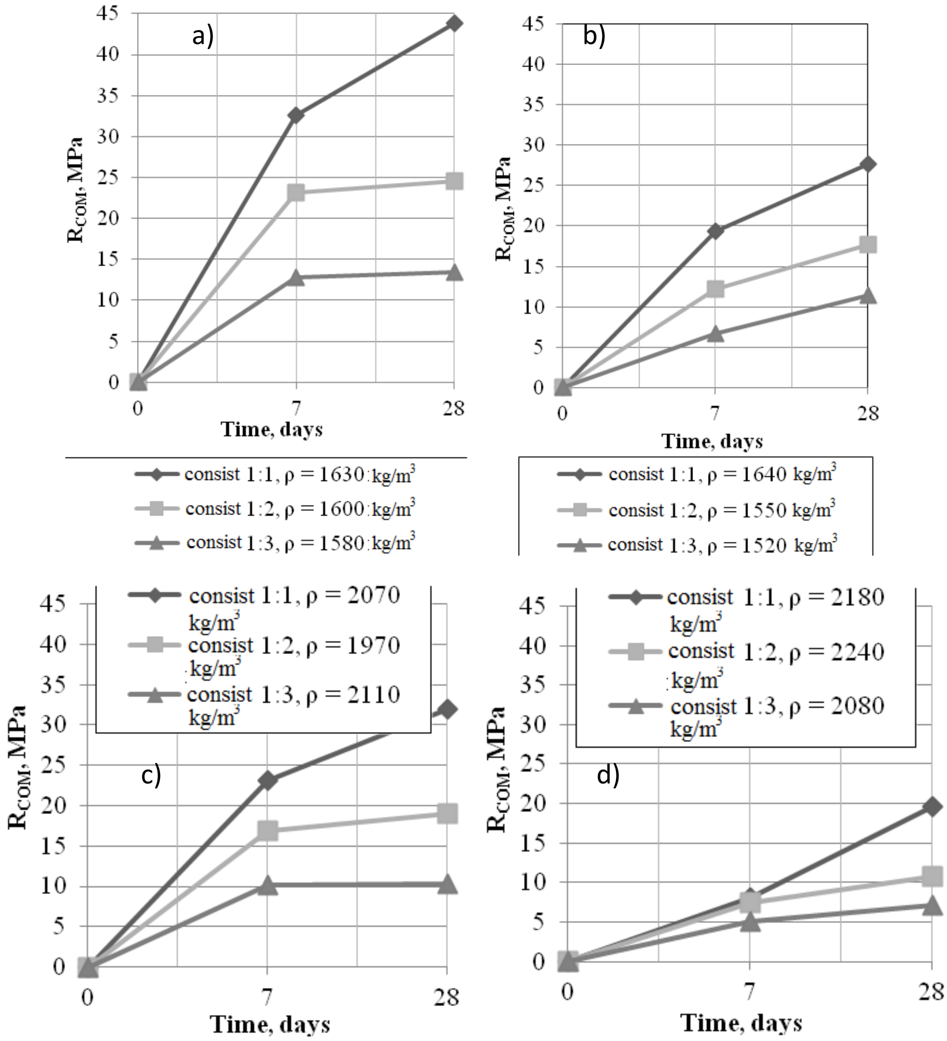

Figure 3. Properties of fine-grained concrete (FGC) on the basis of CGB: a - FGC on the slag sand with mineral additive of slag; b - the same, with mineral additive of bottom-ash; c - FGC on quartz sand with mineral additive of slag; d - the same, with mineral additive of bottom-ash

It is found that the nature of the dependencies of strength of fine-grained concrete on CGB on the V/Binder value is similar to the nature of these dependencies on

Portland cement, at this the concrete strength on the slag sand (in equally mobile mixtures) is higher than on the quartz sand.

Microanalysis of fine-grained concrete structure and elementwise chemical analysis carried ou on a scanning electron microscope Teskan MIRA 3, showed (Fig. 4) that the main crystalline newgrowths are calcium sulfate dihydrate, calcite and low-basic hydrated calcium silicate.

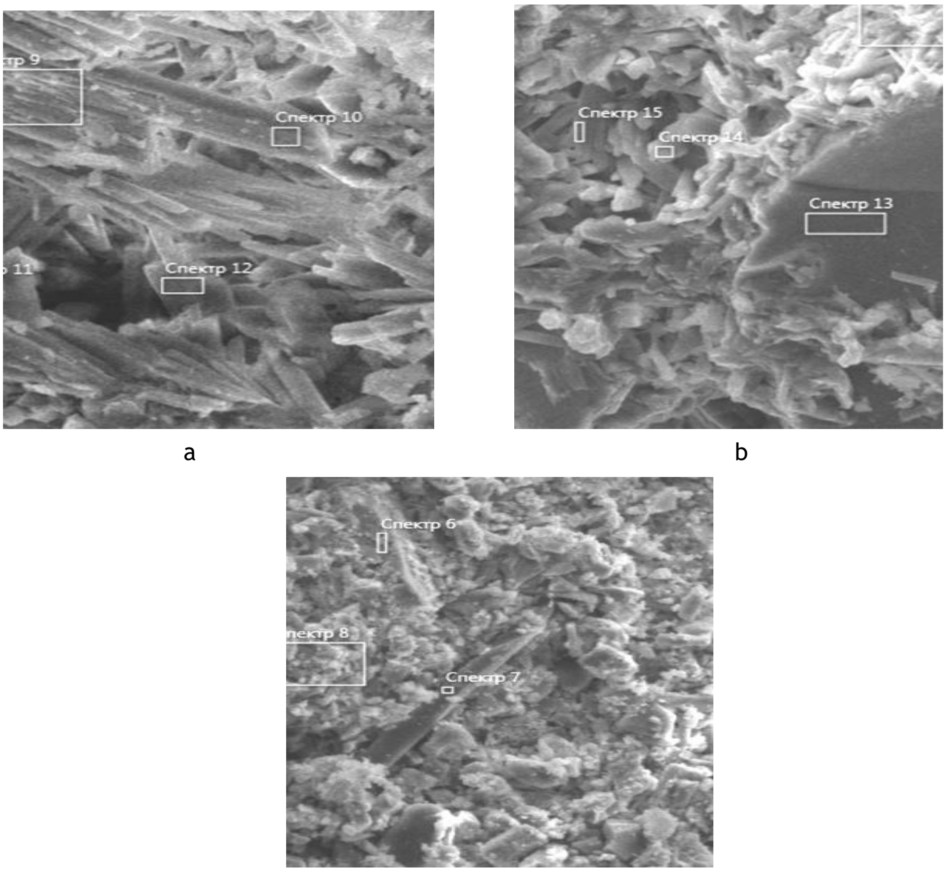

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Figure 4. Micrographs of fine-grained concrete structure on CGB at the age of 1 year (an increase by 5,000 times); a - concrete on slag sand (CGB with ash); b - the same on quartz sand (CGB with ash); c - the same on quartz sand, compressed (CGB with slag)

In the concrete on the slag sand the particles are combined into continuous, with strengthened links between the crystals, structure (Fig. 4a). Available pores almost entirely overgrown by newgrowth with fine-crystalline structure (≤0,1 mkm), presumably NaA silicates, hydroalumosilicates, calcium hydroalumoferrites and calcium sulfate dihydrate as a result of hardening of Portland cement and hemihydrate of calcium sulfate. There is hydrocarboaluminates formation of calcium containing in its formula CO_3 ions of $CaAl_2(SO_3)_2(OH)_4 \cdot 6H_2O$ type, as well as the increase in contact surface between the crystalline hydrate newgrowths, resulting in increase of strength characteristics of the material.

In concrete with quartz sand is formed a porous open-grain structure with a significant number of pores, as well as large and small pores between the crystals of newgrowths (Fig. 4b).

In compacted (20 MPa) concrete samples with quartz sand is formed more dense fine-grained structure with small pores between the crystals of newgrowths (Fig. 4c). Hydrated calcium silicate acquire morphology of dendritic like formations, creating a firm shell around the gypsum particles.

Accumulation of insoluble newgrowths enables hydraulic (first in air and then in water) hardening of concrete on the basis of CGB with ash or slag.

For adequate and qualitative assessment of properties of concretes on the basis of CG were studied their strength and stress-stain properties, used in design calculations - prism strength, elasticity modulus, Poisson's ratio, etc. (table 4).

Table 4. Strength and stress-stain properties of fine-grained concrete on CGB with fly ash in the age of 28 days

№ s.n.	Identifi-cation o set of samples	Average density, kg/m^3	Cubic strength R_{cub}, MPa	Prism strength, R_{pr}, MPa	R_{pr}/ R_{cub}	Elastic modulus E_b, MPa	Poisson's ratio,	Water absorption capacity % mass
1	Concrete on the basis of CGB with slag sand	1520	11.4	10.0	0.88	9230	0.23	3.6
2	Concrete on the basis of CGB with quartz sand	2080	7.1	6.5	0.91	14000	0.32	1.8

In addition, the proportionality actor of fine concrete shrinkage are within the requirements of the regulations, swelling strains are growing rapidly in the first months and exceed shrinkage strains with subsequent stabilization. For concrete of harsh mixes (CGB composition: slag = 1: 2) after six months they do not exceed 0.4 mm / m, and have damping character, of workable mixtures - 0.5 mm / m.

It is found that with the course of time the strength limit and softening factor of fine-grained concrete slightly increases. There were obtained wall materials on the basis of local raw materials of the Chechen Republic, including man-made, class B15 or higher (depending on the composition and method of compaction) and the softening factor 0,66-0,73.

Ability to fine-grained concrete on the CGB basis to hydraulic hardening was studied during 90 days in terms of their compression strength (Fig. 5).

CGB on the basis of bottom-ash waste of CHP is promising for the production of small-piece wall materials from the viewpoint of environmental friendliness, ease of production, convenience of use due to the short setting time, etc.

The study of the nature of the effect of silica-containing components of man-made raw materials on the processes of structure formation of the "gypsum - cement - slag mineral supplement - SP - water" system at hardening of waterproof CGB, allowed to find that in the first stage the rapid gain of system strength is happened at the expense of synthesis of large crystals of calcium sulfate dihydrate, simultaneously performing the function of a controlled early setting.

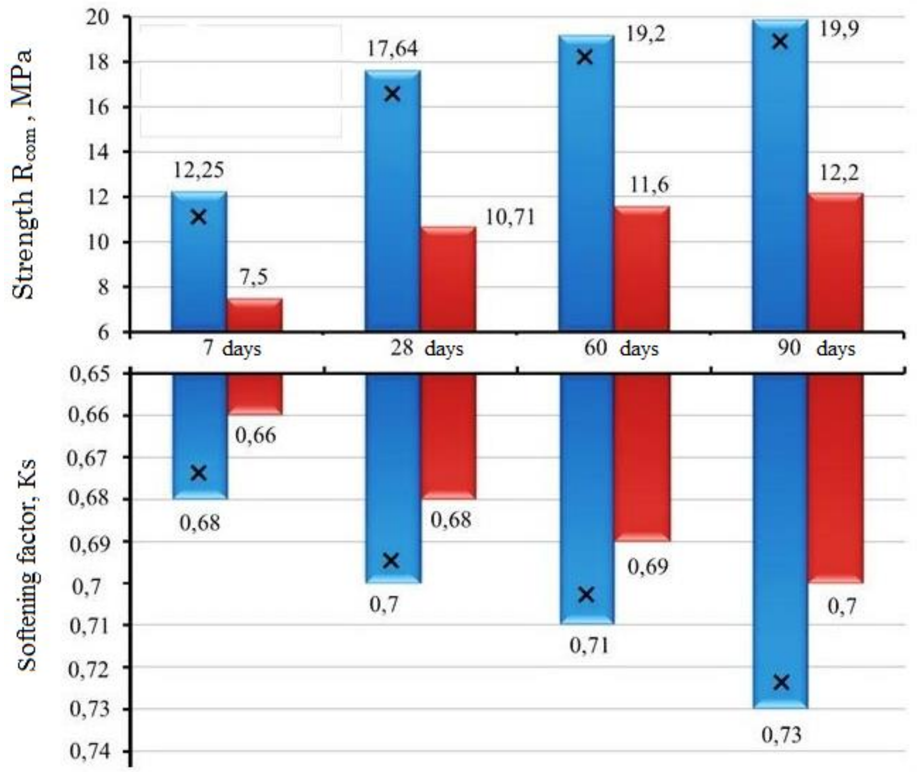

Figure 5. The dependence of the compressive strength and the coefficient of softening of the FGC based on CGB on its age: ☒ - FGC with fly ash and slag sand; ■ - FGC with fly ash and quartz sand

In the future, the clinker minerals hydration provides, by creating a poorly soluble tumors in previously created composite structure, improvement of its water resistance. Subsequent performance growth is provided by newgrowth of 2nd generation of Ca hydrosilicates due to the interaction of released portlandite at alite hydration with X-ray-amorphous particles of bottom-ash mixture. This CGB hydration mechanism minimizes the internal stresses and volume deformation, and therefore reduces the number of microcracks, which leads to increased efficiency of the synthesized CGB in comparison with the traditionally used gypsum binder.

Study of the mechanism of action of chemical additives (superplasticizer Polyplast SP-1, citric acid) in CGB allows to control the rheological properties of mixtures and technical characteristics of concrete. At a dosage in an amount of 0.1-0.5% by weight of the binder, superplasticizer Polyplast SP-1 significantly increases the mixture workability (from 0.12 to 0.22 m). It was revealed that the effective setting time retarder is citric acid. At citric acid dosage of 0.03-0.07% slows down the start of the setting from 8-00 to 34-30 minutes. It was found that the developed complex chemical additive (0.05% citric acid + 0.3% Polyplast SP-1) allows adjusting the beginning of setting up to 30 minutes and hardening rate of CGB.

Conclusion

Thus, it was experimentally proved the effectiveness of the integrated use of man-made materials in the production of fine-grained concrete for small sized wall materials. There were studied the microstructure and morphology of the floured ground mineral additives of the slag and fly ash, used as fillers in CGB. It was determined the dependence of the compressive strength limit and the softening coefficient on its age, as well as i was determined the effect of micro- and macrostructure of fine-grained concrete on the basis of CGB on performance of fine-grained concrete proposed for the production of wall materials and studied their strength and deformation characteristics.

Disclosure statement

No potential conflict of interest was reported by the authors.

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