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Ecological Aspect of the Usage of Ahy and Slag Waste in the Chechen Republic

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***Abstract*—Nowadays the development of new efficient composites based on secondary resources for high-rise construction is a relevant issue. The basis of the production of high-strength concrete is based on modern technological methods that improve technical, physic and mechanical properties, with the integrated application of industrial raw materials and effective chemical additives. The article presents the compositions and studies the properties of high-strength concretes on enriched aggregates and mixed binders with fine ash filler.**

Keywords—industrial raw material, ashy binder, bottom-ash compounds, wastes of the fragmentation of the rock, superplasticizer, ashy microspheres, high-strength concrete, crusher-run aggregate

I. Introduction

The global increasing industrial production entails the accumulation of huge volumes of industrial or man-made waste, the elimination and storage of which present economically and ecologically difficult task. Therefore, the resource-saving technologies for the production of modern building composites are of particular interest and industrial waste is becoming a valuable and scarce raw material of considerable practical interest in the production of building materials, allowing to satisfy raw material requirements up to 40% [1, 2, 6, 7].

The scientific and theoretical studies conducted in this field [3-5, 8, 9] prove that the use of sludge, slag, ashy waste and waste of mining and processing plants, oil refining, etc. provides an opportunity to receive not only traditional, but also new, more effective building materials with a wide range of improved technical characteristics.

A particularly large amount of secondary industrial wastes in the form of ashes and slag, as well as their compounds, is formed when solid fuels are combusted. Depending on the origin of fuel, the amount of generated waste is: in coal – up to 40%, in brown coal – up to 15%, in anthracite and fuel peat – up to 30%, in combustible shale – up to 60% [1, 2, 10]. The usage of ashy and slag raw materials in the production of building materials has a very wide range: road construction, production of composite binders, micro fillers, various types of concrete, aggregates, etc.

Since the 30s of the last century and until the beginning of the crisis events in the Chechen Republic taking place at the turn of the century, there was a lot of Heating Power Plants (HPP) operating in the Republic. For many years of operation of HPPs thousands of tons of ash and slag wastes were accumulated, occupying vast territories of hundreds of hectares and polluting the environment (Figure 1). In this regard, the complex development with the production of concrete composites is not only relevant, but also very effective.

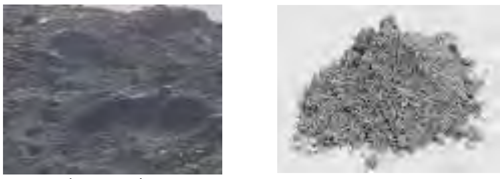

Fig. 1. Bottom-ash waste in Grozny.

II. METHODS AND MATERIALS

However this research presents the results of the study of the properties of fly ash from the HHP of Grozny and the development of ash binders and high-quality concretes based on them. For carrying out the experimental studies, a Portland cement produced by state unitary enterprise “Chechen Cement” CEM I 42.5 N, was used as the main binder, the main properties of the cement studied are shown in Table 1, chemical analysis is shown in % by mass: SiO_2 = 17.45; Al_2O_3 = 3.88; Fe_2O_3 = 3.72; MgO = 1.12; CaO = 71.56; SO_3 = 0.76; TiO_2 = 0.33; K_2O = 1.07; Na_2O = 0.11.

TABLE I. THE MAIN CEMENT PROPERTIES

Producing plant and quality class	Specific surface area, m^2/kg	NC, %	Density, kg/m^3	Setting time, hour - min.		Activity, MPa, 28days	
				The beginning	*The end*	*Compression*	*Bending*
Chechen Cement CEM I 42.5 N	330	25	3100	2-15	3-40	52.6	6.2

In order to obtain ashy cement, ashy and slag wastes of heating power plants were investigated. It was found that they meet the requirements of State Industry Standard 25818-91 “Ashes of heating power plants for concrete. Technical conditions” and their main component are ashy microspheres.

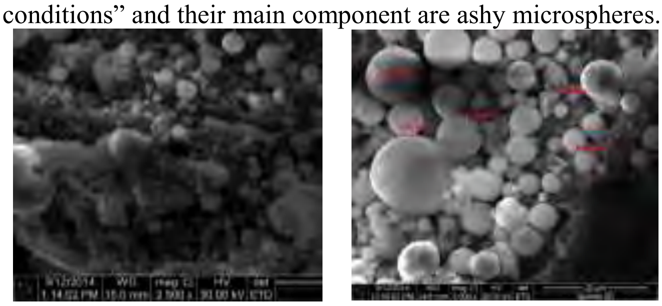

Fig. 2. Micrograph of ashy microspheres.

The study of ashy microspheres with the help of scanning electronic microscope (Figure 2) showed that they are presented by fine particles of gray color, spherical shape and brilliant smooth surface, the unevenness of various structures and sizes along with closed porous shells of individual microspheres were found. Chemical analysis of ashy microspheres is in % in mass: MgO = 1.49; Al_2O_3 = 23.89; SiO_2 = 62.88; K_2O = 0.48; CaO = 1.7; Fe_2O_3 = 7.95; TiO_2 = 0.11; SO_3 = 0.06; ppp= 0.9.

The analysis of the conducted studies showed that the basicity of ash K is an important indicator that determines the processes of structure formation and the formation of the strength of cement stone. It is the ratio of the sum of aluminum and iron oxides to the content of silicon oxide [12, 13]:

$$K = \frac{Al_2O_3 + Fe_2O_3}{SiO_2} \quad (1)$$

For the production of binders with improved properties, ashes with a K coefficient less than 0.8 are recommended; for the studied ash a coefficient is 0.5. This indicator shows the presence of vitreous aluminosilicate phases activating the process of hydration of solid glass in alkaline medium [1, 2].

III. RESULTS

Further recipes of ash binders were developed, but before they were prepared, the ashes of heating power plants were subjected to mechanical activation for 40 minutes. The process of fine grinding in a mill contributes to the destruction of vitreous phase of a shell around ashy microspheres and reveals active crystallization centers on the surfaces capable of a pozzolanic reaction, and also provides a higher degree of homogenization of all the components of the resulting cement. The specific surface area was Ssp = 920 m^2/kg. The degree of saturation of the binder with a fine ashy powder was determined experimentally, and the best ratio was 30% of ashy microspheres (AM) and 70% of Portland cement (PC). The results of the study of the properties of the resulting ashy cement are shown in Table 2.

TABLE II. THE MECHANICAL AND PHYSICAL PROPERTIES OF ASHY CONCRETE (30 % AM AND 70 % PC)

Characteristics	Requirements (SIS 31108-2003)	Actual characteristic
Strength in 28 days, MPa		
- Bending	No limitations	8.7
- Compression	Not less than 42,5	72.0
Strength in 3 days, MPa		
- Bending	No limitations	4.55
- Compression	Not less than 20,0	21.0
Specific surface, m^2/kg	No limitations	520
Sulfur oxide content (VI) SO_3, %	Not more than 4,0	3.5
Normal consistency of cement test, %	No limitations	26.0
Setting time (h: min)		
- the beginning	not earlier than 60 min	2:50
- the end	No limitations	4:10
Uniformity of volume change (expansion), mm	Not more than 10,0	1,5
Specific effective activity of natural radionuclides, Bk/kg	Not more than 370	73

The activity of the resulting ashy binder was 72 MPa, the Figure 3 shows the kinetics of the strength of the developed cements. The studied properties of the resulting ashy binder confirmed the effectiveness of the developed cement, and at the next stage high-strength concrete was designed using it.

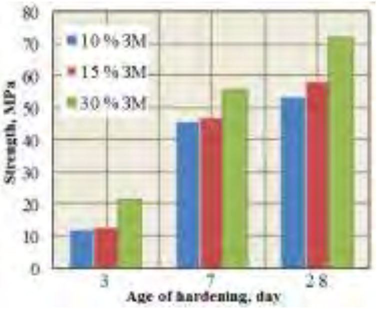

Fig. 3. The kinetic of the set of ashy binder strength.

Due to the lack of high-quality coarse sands in the region, fractionated fine aggregates were used, obtained by mixing fine sand of Chervlenskoye deposit Mkr = 1.7 and screening of rocks crushing of Argun open pit Mkr = 3.2 in the ratio of 1: 1. (The ratio was determined experimentally).

According to approximate statistical data, up to 350 thousand m^3 per year of waste in the form of dispersed stone dust, chips, stone crushing screenings are formed and accumulated at non-metallic plant materials in the region. The Figure 4 shows the surface relief and the morphology of these particles [1, 2, 14-16].

These products are distinguished by an acute-angular shape and a relief surface of particles, and the grain composition of stone crushing wastes is mainly represented by fractions 2.5-1.25 mm and particles less than 0.16 mm, which provides better adhesion in the zone of contact of artificial sand with the cement component and positively affects the strength of concrete.

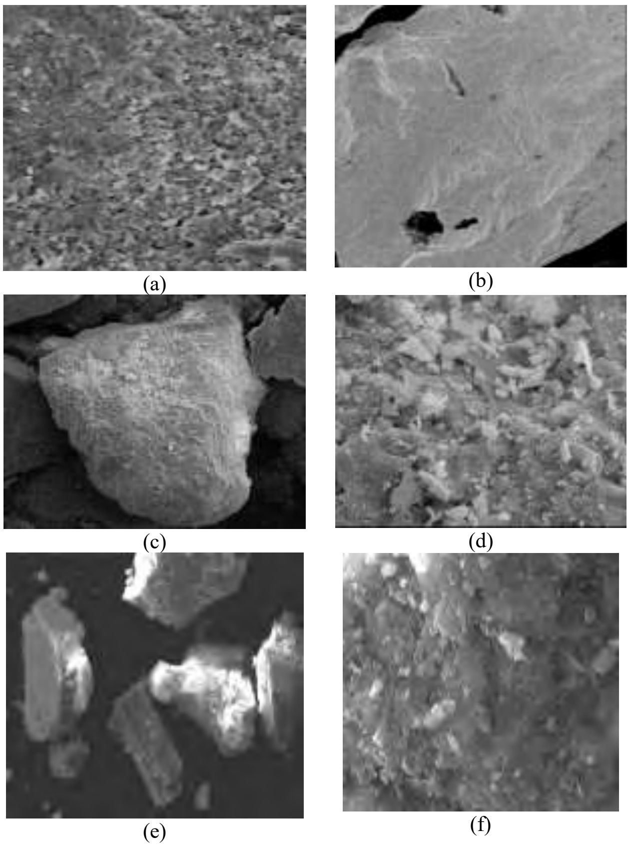

Fig. 4. The shape and morphology of particles surface of waste stone crushing in Argun deposit: a) the particles surface of waste stone crushing in a washed state; b) the earthy structure of individual grains; c) a grain of particles of waste stone crushing; g) the surface of grain wastes stone destruction; e) grains of cube-shaped and flaky shape; e) dense coating on the surface of quartz from a clay substance.

Taking into account the economic side, it is necessary to note that the cost of aggregate from crushing waste is significantly lower (up to 6-10 times) than natural sands, and their use reduces the cost of 1 m^3 of concrete by 10% [1,5-7]. The main properties of the fractionated aggregate are shown in Table 3; Figure 4 shows the sieving curve of the sands obtained.

TABLE III. THE MECHANICAL AND PHYSICAL PROPERTIES FRACTIONATED FINE AGGREGATES

Sieve size, mm	**5**	**2.5**	**1.25**	**0.63**	**0.315**	**0.14**	**bottom**
Partial residuals, %	4.7	10.9	7.3	12.0	50.8	12.6	1.7
Complete residuals, %	4.7	15.6	22.9	34.9	85.7	98.3	
Size modulus	2.62						
The content of dust and clay particles, %	2.4						
Real density, g/sm³	2.56						
Bulk density, g/sm³	1.528						
Void ratio, %	42.4						

To obtain high-strength concrete, cube-shaped stone of the Alagirskoye deposit from granite-diabase rocks of a fraction of 5-10 and 10-20 mm was used, the strength of crushed stone is M1200, it was purchased for tests from the Republic of North Ossetia-Alania. At the same time, the coarse aggregate consisted of a compound of fractions of 5-10 mm and 10-20 mm with a ratio of 70:30 %. The main physical and mechanical properties of coarse aggregate are shown in Table 4.

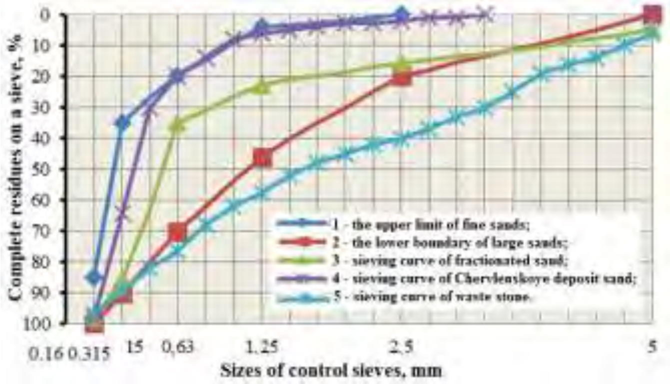

Fig. 5. The sieving curve of fine sands.

The last component used to obtain high performance concrete is a super plasticizer from Russian producers called Polyplast SP-1 based on polycarboxylate ethers, the additive was added with mixing water in various dosages, but the class of concrete mix on mobility remained constant P4 [4, 6, 13].

TABLE IV. THE MAIN PROPERTIES OF COARSE AGGREGATE

Parameter name		Parameter value				
Grain composition of broken stone	Size of sieves, mm	12.5	10	7,5	5	<5
	Partial residues, %	0.0	9.2	38.6	42.5	9.3
	Complete residues, %	0.0	9.2	47.8	90.3	99.6
Strength test		M1200				
The content of dust and clay particles, %		0.8				
Real grain density, g/sm^3		2700				
Bulk grain density, g/sm^3		1450				
The content of broken grain, %		85.2				
Determination of the content of grains of lamellar (flaky) and needle-shaped forms,%		12.2				
Void ratio of stone, %		44.9				

A concrete compound was obtained from the studied components with a draft of a cone from 16 to 20 cm, which corresponds to the grade of mobility P4. Later 6 cubic specimen with a 10 cm edge were formed from the concrete compound of each composition/ They gained strength in the aging chamber with a relative power of 90% at a temperature of 20±20 ° C and they were subjected to a certain period of time. Table 5 shows the experimental compositions of the studied concretes and test results.

TABLE V. THE COMPOSITIONS AND PROPERTIES OF HIGH-STRENGTH CONCRETE

№	Consumption, kg for 1m^3					W/C	Concrete density, kg/m^3	Water consumption, %	Softening factor, F_s	Density for compression MPa	
	AC	*FFA*	*S 5-10 mm*	*S 10-20 mm*	*W*					*7*	*28*
Polyplast additive consumption, 1,3 %											
1	460	870	617	265	170	0.37	2320	7.1	0.77	20.8	41.1
2	480	870	600	252	178	0.37	2350	6.5	0.83	22.5	63.4
3	500	840	610	262	185	0.37	2390	6.3	0.81	25.1	64.2
4	520	860	600	270	192	0.37	2380	6.1	0.85	29.7	65.0
5	520	810	600	300	192	0.37	2400	5.2	0.88	40.9	66.8
Polyplast additive consumption. 1.6 %											
6	460	870	617	265	161	0.35	2310	6.1	0.78	22.1	42.3
7	480	870	600	252	168	0.35	2330	5.8	0.84	25.6	66.2
8	500	840	610	262	175	0.35	2370	5.5	0.83	26.8	64.7
9	520	860	600	270	182	0.35	2360	5.3	0.87	30.1	67.3
10	520	810	600	300	182	0.35	2380	4.1	0.89	43.6	70.7
Companion specimen											
11	500	840	610	262	285	0.57	2410	9.5	0.63	16.3	40.2

Note: AC – ashy concrete (30 % – ashy microsperes of heating power plants; 70 % – Portland cement); FFA – fractionated fine aggregate; S – stone of fractions 5–10 mm and 10-20 mm; W – water.

IV. CONCLUSION

It is necessary to note that the use of ash of Heating Power Plants in the amount of 30% of weight of Portland cement does not significantly affect the first period of hardening. but at 28 days and later terms. the strength evenly increases.

The use of ashy concrete and super plasticizer Polyplast favorably affects the processes of structure formation and the pore space of the cement stone. the consumption of an additive of 1.6% is the most optimal choice. The complex use of secondary resources allowed obtaining a water-resistant and high-strength composite. which has significantly better physical and mechanical properties in comparison with traditional concretes.

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