Multicomponent Binders with Off-Grade Fillers

S.-A. Murtazaev^{1,2,3}, M. Salamanova^{1,2(✉)}, M. Saydumov¹,
A. Alaskhanov¹, and M. Khubaev¹

¹ Millionshchikov Grozny State Oil Technical University, Grozny, Russia
Madina_salamanova@mail.ru

² Ibragimov Complex Research Institute, RAS, Grozny, Russia

³ Academy of Sciences of the Chechen Republic, Grozny, Russia

Abstract. The paper deals with issues related to development of multicomponent binders (MCB) and high-quality concretes based on them. The production of such binders is based on the use of finely divided mineral additives of natural and technogenic origin. Particular attention is paid to the aggregate, the strength of coarse aggregate should be at least 20% higher than the strength of concrete, and the maximum particle size should not exceed 8–20 mm. At present, considerable experience was accumulated for production of multicomponent binders, and the results of studies conducted in this direction showed that the raw material potential of the Republic allowed obtaining high-quality class B30-40 concrete, and if we expanded the geography of the use of natural resources by regions of the North Caucasus, we could produce concretes with higher strength.

Keywords: High-quality concretes · Composite binders ·
Reactive mineral components · Volcanic ash · Thermal power plant (TPP) ash ·
Fractionated filler

1 Introduction

Concrete is one of the oldest materials, but its potential and possibilities seem inexhaustible (Murtazaev et al. 2016; Nesvetaev et al. 2018; Stelmakh et al. 2018), since at all times of its existence and in the future this material will occupy a leading place among a huge variety of building compositions.

The active component of concrete is cement. It is known that varying finely dispersed mineral additives in its composition results in modern composite materials, which properties will vary in wide ranges (Udodov 2015; Salamanova et al. 2017).

In accordance with GOST 31108-2003, granulated slag, fuel ashes, including acidic or basic fly ash, microsilica, burnt clay, burnt shale, marl, quartz sand, etc. are used as mineral components—main components of cement (Udodov 2015; Murtazaev et al. 2016). Various mineral additives can be used as auxiliary components of cement, which will not significantly increase the water demand of cement and reduce durability of concrete.

2 Methods and Materials

As part of the work carried out in this direction, we developed formulations of multicomponent binders, which include mineral additives of natural and technogenic origin.

The North Caucasus has large reserves of natural raw materials for these developments, the chemical analysis of the mineral components used in the studies is shown in Table 1.

Table 1. The chemical composition of mineral components, wt.%

Type	MgO	Al ₂ O ₃	SiO ₂	K ₂ O	CaO	Fe ₂ O ₃	TiO ₂	SO ₃	LOI
TPP ash	2,49	23,89	42,88	0,48	4,6	7,95	0,11	0,66	16,9
Volcanic ash	0,20	13,57	73,67	6,00	1,79	1,52	2,85	-	0,40
Limestone flour	0,72	1,55	5,05	0,6	90,14	1,4	-	0,49	-
Quartz powder	6,32	14,99	73,83	1,83	0,6	0,97	1,32	0,14	-

3 Results and Discussion

To produce multicomponent binders, the additives under study were ground in VM-20 laboratory ball vibratory mill for 30 and 40 min. Figure 1 shows dependence of specific surface of mineral additives on the grinding time.

Fig. 1. Specific surface of mineral components

To determine the optimal degree of saturation of Portland cement (PC) – mineral powder (MP) system (PC:MP), samples were prepared from the proposed multicomponent binder formulations and properties (Table 2).

Table 2. Properties of multicomponent binders (MCB)

No.	Mineral Powder	PC:MP	Normal density, %	Setting time, hour-min		Activity, MPa
				start	end	
1	Limestone flour	70/30	25,5	2-05	3-00	35,8
2		60/40	26,8	2-15	3-20	30,4
3	Quartz powder	70/30	24,6	1-30	2-10	41,8
4		60/40	27,0	1-55	2-50	39,7
5	TPP Ash	70/30	26,4	2-10	3-15	34,1
6		60/40	28,1	2-25	3-35	28,2
7	Volcanic ash	70/30	25,2	1-35	2-15	42,6
8		60/40	26,5	2-05	3-00	40,3
9	–	100	25,0	2-20	3-40	48,0

The results of the studies showed that the most rational are the compositions of binders using mineral powders of volcanic ash and quartz powder with a ratio of 70:30%, with a specific surface of 876 m²/kg and 650 m²/kg, respectively, with a typical increase in the activity of the binder and a slight increase in normal thickness, and 30% of portland cement are saved.

Next, a concrete mixture with P2 mobility mark was produced, the samples were subjected to heat and humidity treatment (HHT) in a steam chamber at 2 + 3 + 7 + 2 h at an isothermal holding temperature of 80 °C. Table 3 shows the experimental compositions and properties of the studied concretes.

Table 3. The compositions of the studied concretes

No composition	Mineral powder	Consumption of materials, kg/m ³				Average density, kg/m ³	Compressive strength, MPa	
		MCB-70	ACS	DS	B		After HHT	Age 28 days
1	Limestone flour	450	1100	680	220	2430	43,3	38,4
2	Quartz powder	450	1100	680	210	2410	50,2	45,9
3	Volcanic ash	450	1100	680	215	2415	52,1	46,5
4	TPP ash	450	1100	680	230	2420	37,7	35,9
5	PC	450	1100	680	200	2420	51,5	48,6

Note: PC – Portland cement; ACS – Alagir crushed stone fraction 5–20 mm; FS – fractionated fine filled based on the sands of the Alagir and Chervlensk deposits.

We established that the strength of concrete after HHT is 12% higher than the indicators of the strength of concrete after 28 days of natural hardening. The use of MCB-70 with volcanic ash showed the best results on the compressive strength of

concrete in comparison with other additives and slightly inferior to similar indicators of control samples (Murtazaev et al. 2016; Stelmakh et al. 2018). The study of operational characteristics (Table 4) showed that the indicators of these properties depend on the composition of the MCB-70 and its activity, as well as on the type and value of the porosity of the material.

Table 4. Operational properties of concrete using MCB-70

Indicators	Mineral powder			
	Limestone flour	Volcanic ash	TPP ash	Quartz powder
MCB-70 activity, MPa	35,8	42,6	34,1	41,8
Compressive strength, MPa	38,4	46,5	35,9	45,9
Flexural strength, MPa	4,1	4,9	3,8	4,4
Porosity, %	9,7	7,6	12,4	6,9
Frost resistance, cycle	F300	F350	F200	F350
Pressure, MPa	1,4	1,8	1,2	1,8
Water absorption, %	4,2	3,5	5,2	3,6
Water resistance, Kr - softening coefficient	0,79	0,89	0,63	0,90

4 Conclusions

Multicomponent binders based on mineral powders of natural and man-made origin allow to obtain high-quality concrete of class of strength B30-40, including for high monolithic construction.

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