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Influence of Mechanical and Chemoactivation Processes on Operational Characteristics of Geopolymer Binder

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Abstract: According to contemporary idea of reaction activity of mineral raw materials with increasing in dispersity of aluminosilicate component due to mechanical activation, the tendency of increasing in amorphous phase consentration is observed. It is important to know, the amourphous substanse is more active componemt in geopolymerization process which favorably effects on operational properties of a final product. In order to confirm a given hypothesis of reaction activity of raw materals some of natural and industrial alumosilicate components were studied. In the study, a mathematical relation strength performance of geopolymer binders vs. mechano and chemoactivation parameters of aluminosilicate raw materials was developed.

Key words: Dispersity, mineral law, material, amourphous, chemoactivation, geopolymer

INTRODUCTION

Now a day, one of the main directions to deal with the problem of energy and resources saving in the field of construction material science is a development and application of low-cement or free-cement binders and materials on their base with using of alternative analogues of natural and industrial raw materials (Fomina *et al*., 2013; Zhernovsky *et al*., 2014; Alfimova *et al*., 2013). Geopolymer binders (or geopolymers) produced by alkaline activation of aluminosilicate natural and industrial raw components should be attributed to existing types of resource- and energy-efficient binders.

According to a structure formation mechanism in geopolymer system, one of the basic parameters which is responsible for chemical processes and physical-and-mechanical properties of geopolymer stone is a pH index of system at early curing stage.

Reffering to the data presented in Davidovits (1989), Kozhukhova *et al.* (2012) and Kalashnikov *et al.* (2006), for activation of binder properties of raw components and providing a maximal efficiency of geopolymerization processes followed by structurization and curing of the binder system, it is necessary to achieve a stable high-alkaly medium with pH index which keeps ≥13 value for 12-24 h.

At the same time, there is a hypophesis that with increasing of dispersity of aluminosilicates by mechanoactivation, a portion of a chemically active amorphous substance in geopolymerization reaction is also increased which benefically effects on operational performance of material.

MATERIALS AND METHODS

In order to study an influence of the mentioned parameters on geopolymer characteristics some natural and industrial alumosilicate components were investigated. In this research, perlite rock supplied from Mukhor-Talinsk deposit was used as a natural aluminosilicate. As representatives of industrial aluminosilicate raw materials were taken fly-ashes from Novotroitsk power station and Troitsk hydraulic power station. Sodium hydroxide according to Russian Standards 2263-79 was used as alkaline component for a good geopolymerization reaction.

Such characteristic of studied raw aluminosilicates as chemical composition (Table 1) were determined with XRF-analysis by using diffractometer ARL9900 x-ray WorkStation (Thermo scientific).

The XRD spectra are obtained with diffractometer ARL X'tra and ARL 9900 X-ray WorkStation by using Cu $\lambda_{K\alpha1,2}$ and Co $\lambda_{K\alpha1,2}$ radiation, respectively. The quantitative full-profile XRD analysis for determination mineral composition of studied aluminosilicates as well as x-ray amorphous phase (Table 2 and Fig. 1) content is performed by using a Rietveld algorithm. To account for

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Table 1: Chemical composition of the aluminosilicates

Al-Si component*	Percentage									
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	K_2O	Na_2O	H_2O	SO_3	LOI
1	75.5	13.60	1.00	1.00	0.30	0.10	4.8	3.8	5.3	-	-
2	58.6	24.30	5.32	2.28	0.48	0.86	0.7	0.4	-	0.3	6.00
3	57.4	32.74	0.48	0.43	2.16	0.08	0.3	1.2	-	-	5.19

*1: Perlite; Fly-ashes from; 2: Novortoitsk power station; 3: Troitsk hydraulic power station

Table 2: Mineral composition of the industrial aluminosilicates

	Percentage					
Title	Quartz	Mullite	Anorthite	Magnetite	Hematite	Glass
Fly-ash (Novotroitsk power station)	10.7	23.5	4.3	1.0	-	60.5
Fly-ash (Troitsk hydraulic power station)	6.4	13.5	-	7.2	4.5	68.4

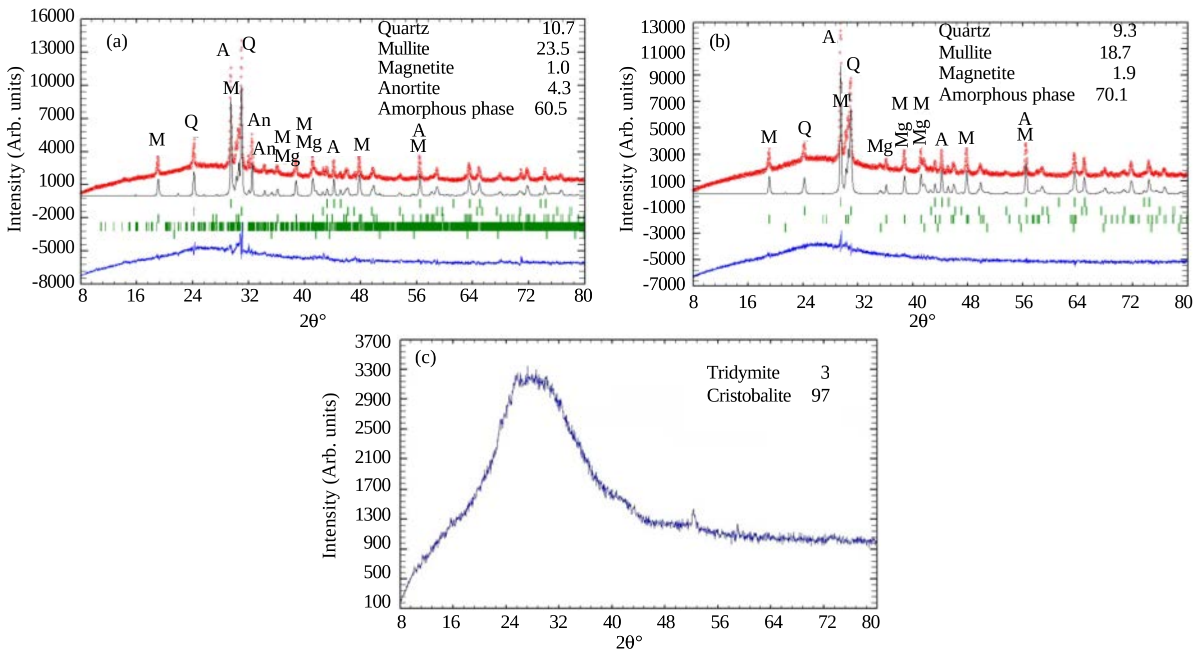

Fig. 1: Data of XRD analysis for: a) Fly-ash from Novotroitsk power station; b) Fly-ash from Troitsk hydraulic power station; c) Perlite rock from Mukhok-Talinsk deposit

x-ray amorphous phase and to avoid the background effects, the Derivative Difference Minimization algorithm (DDM) software is used.

Determination of optimal parameters of geopolymer systems was applied with graphic program sigmaplot.

RESULTS AND DISCUSSION

For determinaton of workability of studied aluminosilicate as component in geopolymer systems analysis of chemical and mineral composition of them was accomplished (Table 1-3).

According to analyses of chemical and mineral composition, the studied aluminosilicates are considered as acidic materials with concentration CaO in the system no >10%. It's also should be noticed that in the studied systems was found a high concentration of X-ray amorphous substance which is above 60% for industrial aluminosilicates (fly-ashes) and about 100% (tridymite and cristobalite are X-ray amorphous phases) for perlite.

For determination of compressive characteristics of geopolymer systems based on different types of aluminosilicates the composition of geopolymer pastes were prepared (Table 4).

After moulding fresh samples were placed in oven and cured at 70°C for 24 h. When they were demoulded and cured at ambient conditions (t = 22±3°C) up to 28 day age for realizing strength test.

Table 3: Mineral composition of perlite from Mukhor-Talinsk deposit

Percentage (weight)		Size of crystallites (nm)	
Tridymite	Cristobalite	Tridymite	Cristobalite
3	97	1,6	1

Table 4: Composition of experimental samples of geopolymer system

Type of aluminosilicate component	Composition		
	Fly-ash from Novotroitsk power station	Fly-ash from Troitsk hydraulic power station	Perlite rock from Mukhor-Talinsk deposit
Molar ratio Na_2O/Al_2O_3	0.75	0.75	0.75

One of the basic factor to stimulate structure forming processes of geopolymer binder is a presence of an alkaline activator in the system. In earlier studies, experimentally was found the optimal molar ratio of main oxides of the binder Na_2O/Al_2O_3 for geopolymer binder production with using the studied fly-ashes which is 0.75. For perlite, this paremeter corresponds to 2. Thus, this parameters were used in the study.

Based on the obtained results as well as early researches (Fomina *et al*., 2013; Kozhukhova *et al*., 2013), the studied aluminosilicates with given chemical and mineral characteristics have a potential to be efficient raw materials for geopolymer binders production.

As main varied factors were chosen: molar concentration of alkaline solution in range from 12-19 M and mechanoactivation period of alumosilicate component. Range of molar concentration was chosen according to results of compressive strength (the highest ones), obtained in our investigations earlier as well as on the basis of literature sources (Memon *et al*., 2011; Sumajouw and Rangan, 2006).

For all studied aluminosilicates the most effective mechanoactivation period is 2 h. The obtained optimal ratios were use in the following up study.

To evaluate the effect of genetic percularities of the studied aluminosilicates as well as their chemical and mechanical activation, a planning matrix of the experiment was developed in the frame of the work (Fig. 1).

Based on the data obtained from for the natural and industrial aluminosilicate were plotted as nomographs with SigmaPlot program. Dependence of parameters compressive strength vs. molar concentration of alkaline solution vs. dispergation time was considered (Fig. 2).

The analysis of the obtained experimental data made it possible to determine the proper parameters to produce optimal mixes of binders with the highest compressive strength (Table 5). Thus, for optimal binder mixes mechanoactivation period should take 2 h, molar concentration of alkaline solution is 16M for fly-ashes and 13M for perlite.

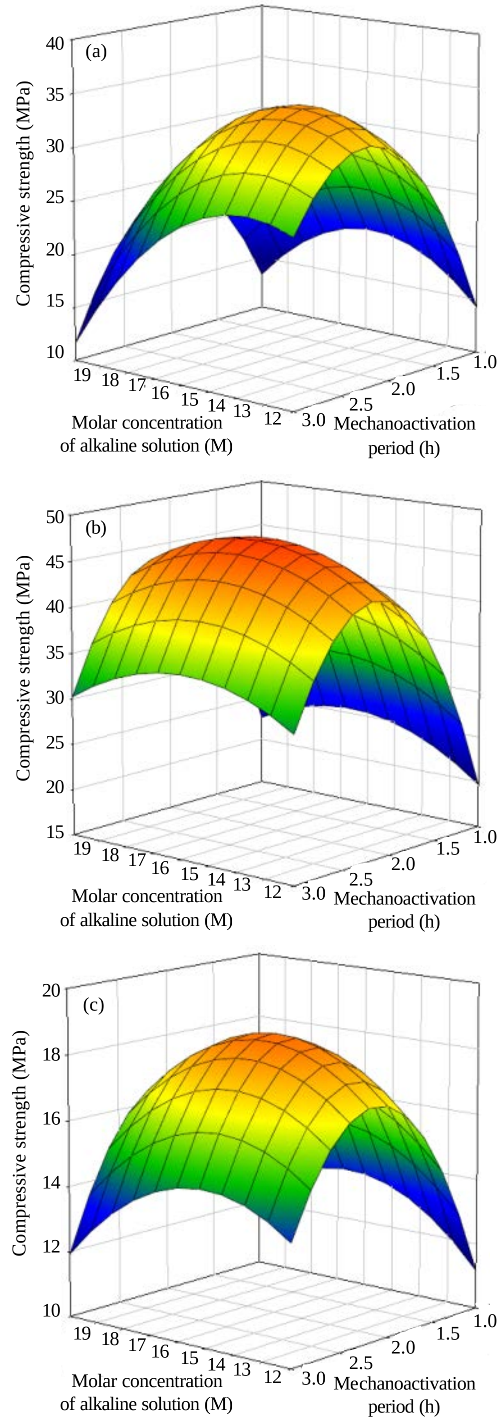

Fig. 2: Compression strength vs.grinding time vs. molar concentration of alkaline solution SigmaPlot nomographs for geopolymers based on: a) Fly-ash from Novotroitsk power station; b) Fly-ash from Troitsk hydraulic power station; c) Perlite from Mukhok-Talinsk deposit

Table 5: Compressive strength of the geopolymer binders

Aluminosilicate	Optimal dispergation time (h)	Molar concentration of alkaline solution (M)	Molar ratio Na_2O/Al_2O_3	Compressive strength (MPa)
Fly-ash (Novotroitsk power station)	2	16	0.75	34.13
Fly-ash (Troitsk hydraulic power station)	2	16	0.75	47.30
Perlite (Mukhor-Talinsk deposit)	2	13	2.00	18.40

CONCLUSION

In the result of analysis of the data obtained in the frame of the research, it can be concluded the studied natural and industrial aluminosilicates with given mineral and chemical characteristics have a potential to be efficient raw components in geopolymer binder production.

Behavior with changing of properties of geopolymer binder was studied depending on chemical and mechanical activation of aluminosilicate raw materials. According to sigmaplot nomographs the optimal molar molar concentration of alkaline solution is 16M for fly-ashes and 13M for perlite. For all studied aluminosilicates the most effective mechanoactivation period is 2 h.

So, the developed SigmaPlot nomographs allow qualitatively and quantitatively evaluate the effect of each parameter separately as well as in the system "composition-properties" that can be applied for manufacturing mix formulations of binders and forecasting of their physical and mechanical performance.

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