Geopolymerization and Structure Formation in Alkali Activated Aluminosilicates with Different Crystallinity Degree

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Abstract. The work presents the results of grain-size analysis of alkali-activated aluminosilicate suspensions with different crystallinity degree. It is found that the crystallinity degree of aluminosilicate is inversely proportional to its solvability in strong alkaline substance. The mechanism of geopolymeric system formation during the geopolymerization process has been suggested.

Keywords: Aluminosilicates · Crystallinity degree · Structure formation · Geopolymerization

1 Introduction

The application of colloid and nano-sized silicate and aluminosilicate components for the synthesis of effective binding systems is one of the most attractive directions in the science of construction materials (Vivian et al. 2017; Dmitrieva et al. 2018; Sobolev 2016).

The earlier studies (Shekhovtsova et al. 2018; Galindo Izquierdo et al. 2009) discussed various factors influencing the ability of alkali activated cements to form the aluminosilicate structures from the anthropogenic aluminosilicates, in particular fly-ash (Kozhukhova et al. 2018; Wang et al. 2018).

2 Materials and Methods

To estimate the viability of the research hypothesis three types of natural aluminosilicates with a different crystallinity degree were used:

- Obsidian - effusive rock of an acidic composition and amorphous structure;
- Pearlite - effusive rock of an acidic composition and crypto-crystalline structure;
- Crouan – intrusive compound acidic rock with a hollow crystalline structure.

To prepare alkaline silicate suspensions the equal volumes (50 g) corresponding to each sample of milled aluminosilicate material were placed into glass bottles and mixed with 50% NaOH water solution.

These suspensions were mixed for three days (72 h) using a LS-110 mixing device. The specific surface and the average size of grains of aluminosilicate powders was performed using a laser analyzer ANALYSETTE 22 NanoTec plus.

3 Results and Discussions

This report is based on the hypothesis that during the alkaline activation of aluminosilicate particles the dissolving process is gradual, starting with the dissolution of surface layers. As the result, the alkali aluminosilicate gel is formed which acts as a binding base for further geopolymerization. At the same time, the aluminosilicate component crystallinity degree influences its solubility in the alkaline medium.

To test the research hypothesis the average size of the aluminosilicate particles average size was determined as well as the specific area in the initial condition and also after the alkaline activation (Table 1).

Table 1. The particle size and specific area of aluminosilicate powders after the alkaline activation

№	Aluminosilicate type	Average particle size, μm		Change, %	Specific area, m^2/kg		Change, %
		Before activation	After activation		Before activation	After activation	
1	Crouan	11	9	–16	910	1003	10
2	Perlite	11	14	21	838	774	–7
3	Obsidian	14	17	23	785	642	–18

The results of grain size analysis for crouan after the alkaline activation prove that the average particle size is reduced relative to the particle size before activation. It may be caused by crouan grains subsolution resulting in the reduction of the particle size.

At the same time in the alkaline activated suspensions of perlite and obsidian there is a tendency of particle size increase in comparison with those before activation.

Hence, for crouan there is an increase of the specific area of the solid phase after the activation and a decrease of average particle size.

In case of perlite and mostly obsidian, the alkaline activation has a reverse effect: the specific area decreases and the average particle size increases (Fig. 1).

The received data of the grain size analysis suggested a scheme of aluminosilicate structure formation that occurs during the geopolymerization. This scheme includes two simultaneous processes: the dissolution of the aluminosilicate component and the formation of the alkali aluminosilicate gel, which is the chemical interaction of alkali aluminosilicate gel with unreacted grains. The chemical interaction causes the formation of a «gel layer – unreacted grain» in investigated system.

Fig. 1. The structure formation mechanism in the system “gel layer – unreacted grain of aluminosilicate component” during the alkali activation.

The lower aluminosilicate crystallinity degree results in a high intensity of the dissolution of aluminosilicate particles and a thicker surface gel layer based on the newly formed compound.

4 Conclusion

The crystallinity degree of aluminosilicates is inversely proportional to the reactivity in alkali systems, which is controlled by the solubility degree in highly alkali medium. Based on this observation, it was suggested that the geopolymerization scheme in the system «gel layer – unreacted grain of aluminosilicate component» occurs during the alkaline activation.

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