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Preparation of geopolymer from fluidized bed combustion bottom ash

R. Slavik[a,*], V. Bednarik[a], M. Vondruska[a], A. Nemec[b]

[a] Tomas Bata University in Zlin, Faculty of Technology, Department of Environment Protection Engineering, 762 72 Zlin, Czech Republic
[b] Atel Energetika Zlín, Ltd., 76001 Zlin, Czech Republic

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ABSTRACT

This study has shown that it is possible to use fluidized bed combustion bottom ash (FBC-BA) without any thermal activation as a partial- or full-replacement for kaolinitic raw material in geopolymerization. Test specimens prepared from FBC-BA have reached compressive strength of almost 50 MPa after 90 days of hardening. After 50 freeze-thaw cycles, the compressive strength of test specimens has not decrease below 80% of compressive strength of unaffected reference specimens, which represents an acceptable freeze-thaw resistance. Testing of wet-dry resistance has shown that wet-dry cycles cause an increase of the compressive strength values. Testing of acid resistance of prepared geopolymer specimens has shown that replacement of usual kaolinitic raw material by FBC-BA results in slight increase of leachability.

1. Introduction

At present, we are witnessing an intensive research in the field of geopolymer synthesis and preparation of new technically applicable materials from these geopolymers (Davidovits, 1991, 1994, 2005; Xu and Van Deventer, 2000). As it is known, the basic raw materials used for geopolymer synthesis are aluminosilicate minerals such as kaolinite, albite, stilbite (Xu and Van Deventer, 1999, 2003, 2002). These raw materials have to be transformed into reactive form by several hours heating at approximately 750 °C before the geopolymer synthesis. This process, called activation of basic raw material, requires appreciable energy consumption.

In the presented paper, a replacement of classical aluminosilicate raw material by fluidized bed combustion bottom ash (FBC-BA) is tested. Fluidized bed combustion is considered as an advanced technology for energy utilization of coal from the viewpoint of both gas emission reduction and economical feasibility (Valk, 1995). FBC-BA is a by-product that has got a convenient chemical composition from the point of geopolymer synthesis (Bednarik et al., 2000) and, as well, it is a material produced at temperatures around 800 °C with detention time of a few hours. The mentioned temperature and time represent almost ideal conditions for activation of kaolinitic raw materials needed for geopolymer synthesis. The amount of produced FBC-BA is relatively large at present and it will be

* Corresponding author.
E-mail address: slavik@ft.utb.cz (R. Slavik).
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probably increasing in the future (for example, in a town with 80,000 inhabitants, the heating plant produced 4500 tonnes of FBC-BA in the year 2006).

The aim of the presented study is to test possibilities of FBC-BA application for industrial production of technically valuable materials by means of geopolymer synthesis. With regard to the fact that FBC-BA is predominantly disposed to landfills at present, a technology utilizing FBC-BA would offer significant economical and also environmental benefit.

2. Materials and methods

2.1. *Fluidized bed combustion bottom ash (FBC-BA)*

A sample of FBC-BA was supplied by Atel Energetika Zlin, Ltd. (Czech Republic, Europe). A mixture of bituminous and brown coal was being used as the fuel in the heating plant in the time of the sample collection. The sample had the appearance of small grey stones with dimensions up to 1 cm. The sample was firstly pulverized in ball mill to decrease the particle size to 2 mm and the obtained material was subsequently milled in jet mill to final particle size bellow 10 μm, as it is shown in Fig. 1 (particle size distribution was measured by laser particle size analyzer CILAS 920, CILAS U.S., Inc.). It is obvious from the figure that the size of the most frequent particles is 5 μm. An approximate chemical composition of the FBC-BA sample was determined by X-ray fluorescence analysis (XRF); the results are shown in Table 1. If the FBC-BA composition is compared with composition of typical kaolin, which is classical raw material for geopolymer synthesis, it is obvious that FBC-BA contains markedly less SiO_2 and Al_2O_3 and relatively large amount of calcium. Considering the fact that the coal is combusted, stirred and mixed with limestone, the FBC-BA contains calcium in the form of CaO (product of limestone decomposition by combustion), $CaCO_3$ (undecomposed residuum of limestone) and $CaSO_4$ (product of SO_2 fixation). Loss on ignition (LOI) values of the FBC-BA sample at 550 and 800 °C are shown in Table 2. The value of LOI at 550 °C reflects complete combustion of coal residues and the value of LOI at 800 °C includes moreover decomposition of carbonate. From the LOI value at 550 °C it is thus evident that the FBC-BA sample contained 7.5% of uncombusted coal residues. From the difference of LOI values at 800 and 550 °C, considering that the weight loss is caused by the loss of CO_2, the content of undecomposed limestone can be calculated according following equation:

Table 1 – Chemical composition (wt.%) of FBC-BA sample and kaolinitic clay determined by XRF analysis

Oxide	FBC-BA	Kaolinitic clay	Calibration error
Al_2O_3	20.5	23.9	± 0.200
SiO_2	38.2	67.2	± 0.343
K_2O	1.1	0.24	± 0.013
CaO	17.9	0.12	± 0.050
TiO_2	1.3	0.37	± 0.004
Fe_2O_3	5.5	0.35	± 0.005

Analyzed using spectrometer ElvaX (Elvatech Ltd., http://www.elvatech.com).

Table 2 – Loss on ignition of FBC-BA sample

Temperature (°C)	LOI (wt.%)
550	7.5
800	11.0

$$\% \, CaCO_3 = (LOI_{800} - LOI_{550}) \times \frac{M_{CaCO_3}}{M_{CO_2}}$$

where *M* are values of molar mass. The calculated content of $CaCO_3$ amounted to 7.96%. The content of free CaO was

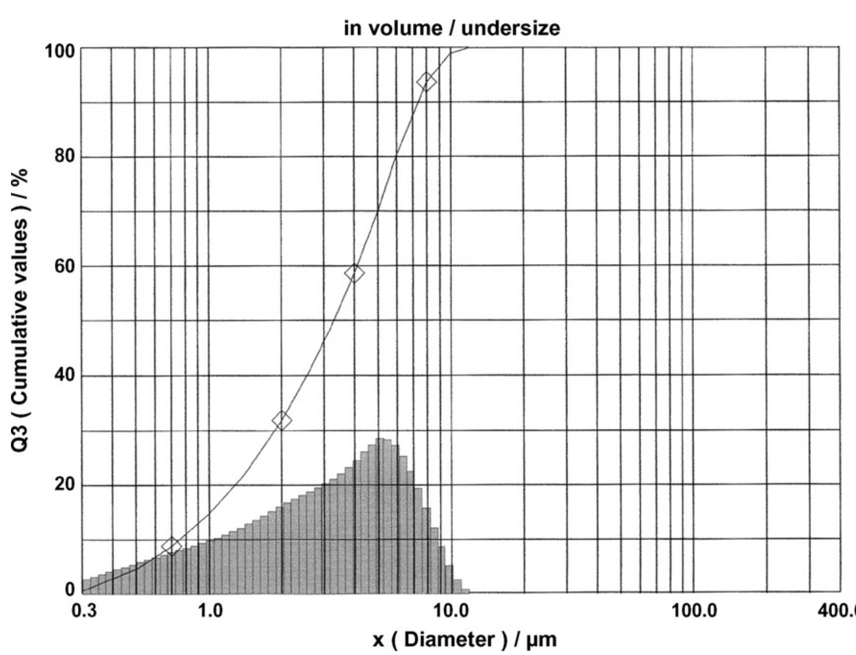

Fig. 1 – Particle size distribution of the milled FBC-BA sample.