Alkali-activated Fly Ash: Integrated Research on an Alternative Aluminosilicate Binder

CZECH TECHNICAL UNIVERSITY IN PRAGUE

INSTITUTE OF CHEMICAL TECHNOLOGY PRAGUE

Z. Bittnar[1], P. Svoboda[1], F. Škvára[2], L. Kopecký[1], J. Doležal[1], R. Šulc[1], P. Houser[1], T. Strnad[1], J. Němeček[1], V. Šmilauer[1], L. Myšková[2], L. Alberovská[2], L. Vinšová[2], M. Vokáč[3]

[1] Czech Technical University in Prague, Faculty of Civil Engineering, Thákurova 7, 166 29 Praha 6, Czech Republic
[2] Institute of Chemical Technology Prague, Department of Glass and Ceramics, Technická 5, 166 28 Praha 6, Czech Republic
[3] Czech Technical University in Prague, Klokner Institute, Šolínova 7, 166 08 Praha 6, Czech Republic

Motivation

The Czech Republic produces fly ash in the quantity one ton per capita a year. The majority of this low-calcium brown coal ash is disposed into mined-out pits while a negligible amount is utilized as a stabilizing material or is blended with cement.

Gluchovskij (1959), Davidovits (1979), Fernándes-Jiménez, Palomo (2005) and others studied the synthesis of a new **aluminosilicate binder** in the form $[Na,K]_m\ [\text{-}(Si\text{-}O)_z\ \text{-}Al\text{-}O]_n \cdot [H_2O]_w$ denoted as ***soil cement***, ***geopolymer***, ***alkali-bonded ceramic***, ***inorganic polymer***, or ***N-A-S-H gel binder***. Slag, fly ash, metakaolin are typical suitable materials for the preparation of the binder; the bond Si-O-Al is broken down in a strong alkaline environment followed with slow polymerization and polycondensation reactions.

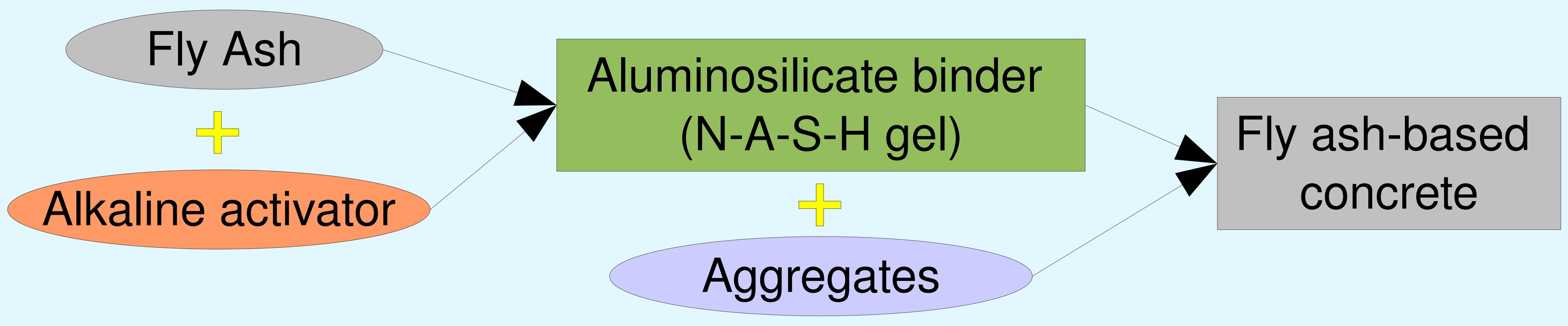
Objectives

Mastering the alkali-activation process is a prerequisite for the synthesis of a new and durable material, far exceeding ordinary Portland concrete in terms of durability, leaching, fire resistance, alkali-silica reaction, or basic and drying creep. Composites based on activated fly ash binder produce negligible CO_2 emissions and utilize the waste material. It is estimated that approximately 20 % of Portland concrete could be instantly replaced with the activated fly-ash. The project pursuits an interdisciplinary approach and knowledge transfer among science disciplines.

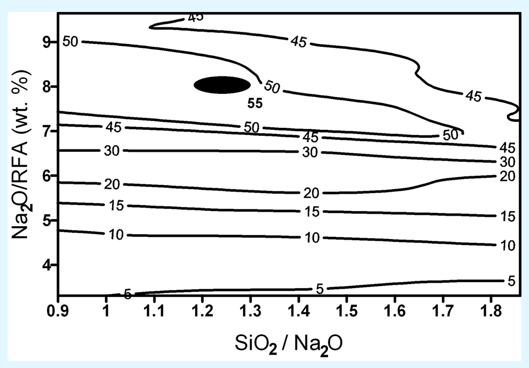
Results and Outlook

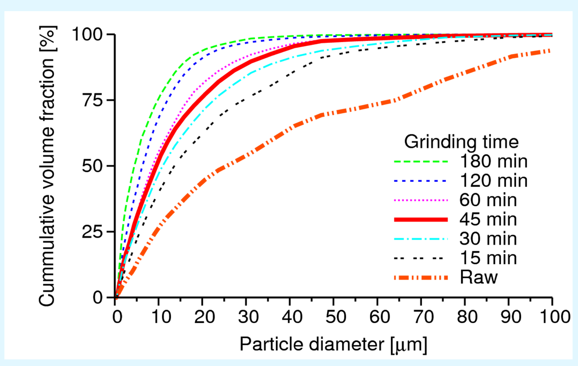
The trademark POPbeton® and small-scale industrial applications emerged as the fruitful project results. However, many questions arose for further research; the nanostructure of N-A-S-H gel, the role of alkalies on efflorescence, utilization of nucleation seeds for progressive ambient curing, chemical and autogeneous shrinkage, or quantification of basic and drying creep.

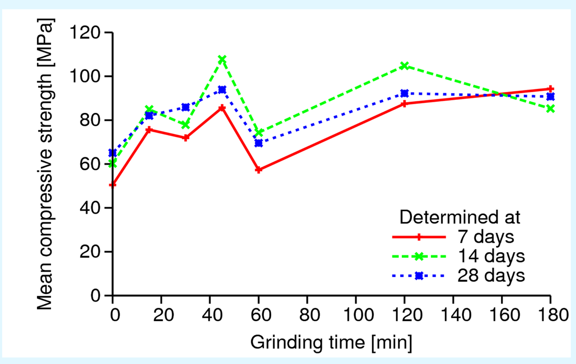
Technology

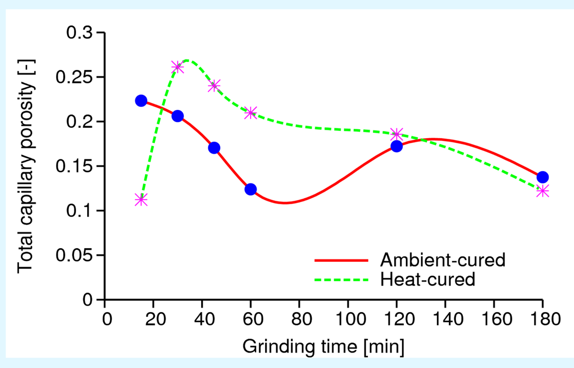



Fly ash with PP fibers before the addition of an activator and aggregates.

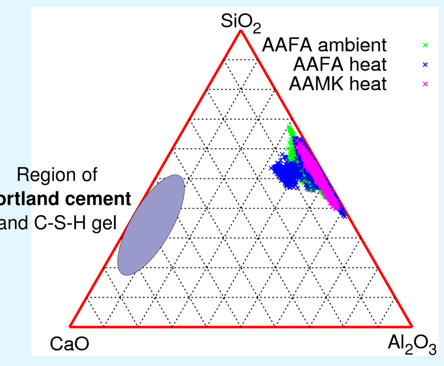

Optimization of two-day mortar compressive strength, constant water/fly ash ratio 0.3, heat-cured samples.

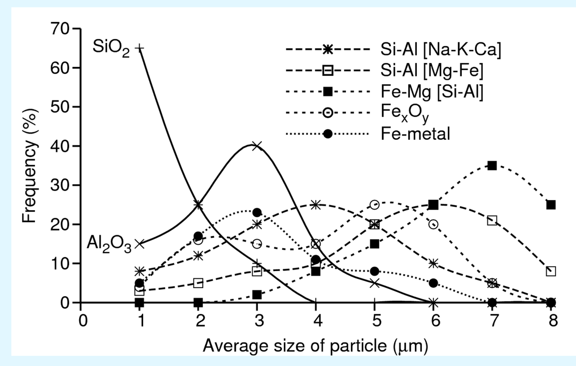

Particle size distribution of ground fly ash. Grinding in the ball mill in the batch weight 25 kg.

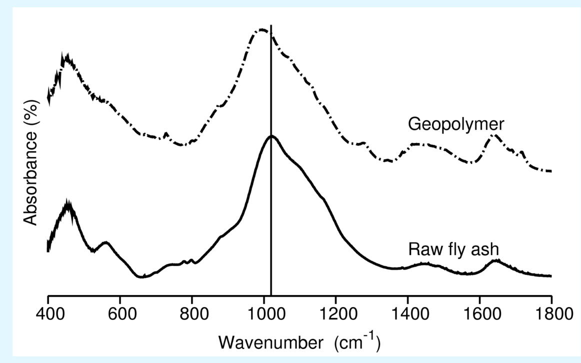

Mean compressive strength at 7, 14, 28 days of ground fly ash's paste. The same activator and mixture proportions were used.

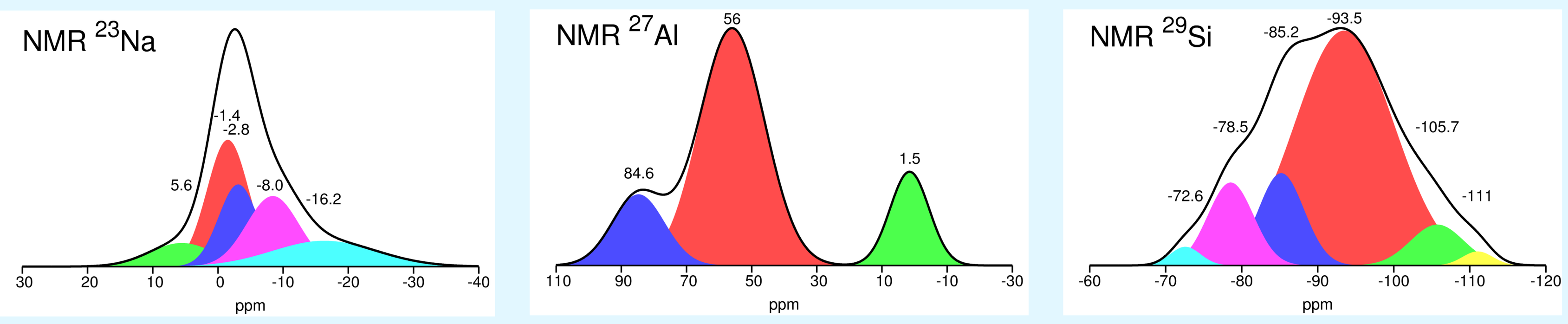

Total capillary porosity obtained from MIP porosimetry and He pycnometry on activated fly ash paste. Ambient- and heat-cured samples.

Chemistry

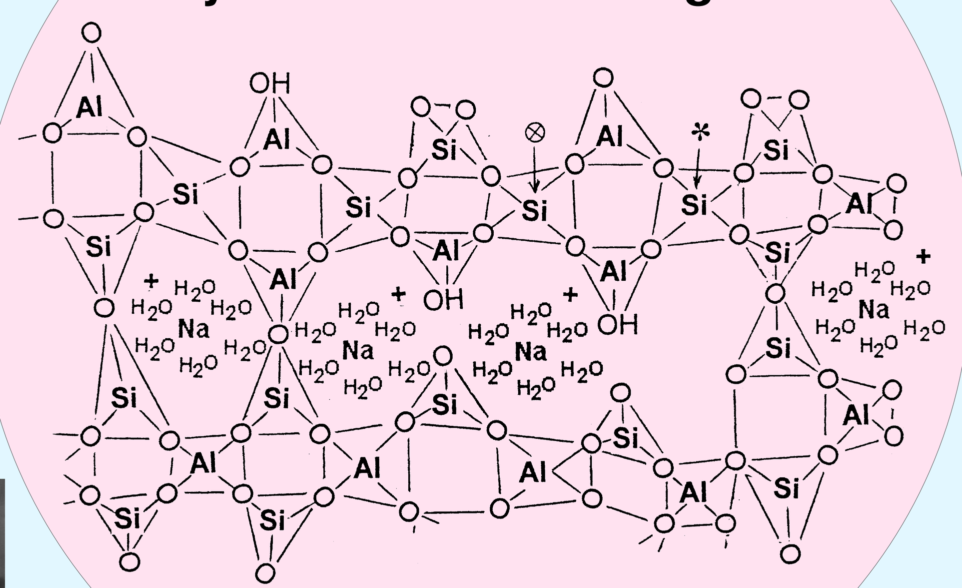

Ternary diagram of alkali-activated fly ash (AAFA) with hydrated Portland cement.


Relationship between the major chemical composition and particle size of raw fly ash.


FTIR spectra of geopolymer paste and raw fly ash.

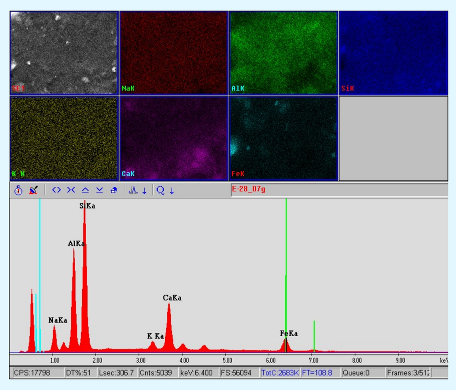

NMR MAS deconvoluted spectra of paste for the deduction of N-A-S-H gel nanostructure.

Nanoscale model of synthesized N-A-S-H gel



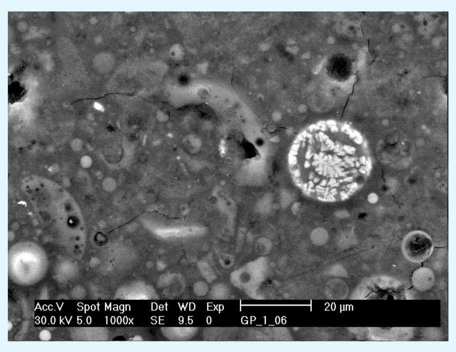
Barbosa *et al.*, 2000

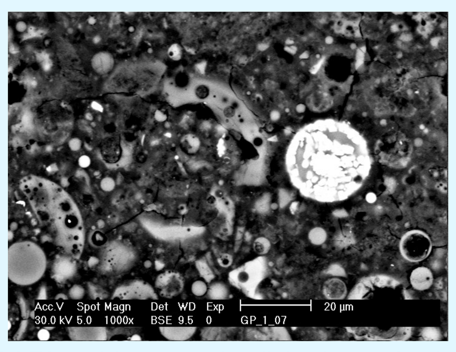
http://geopolymers.net

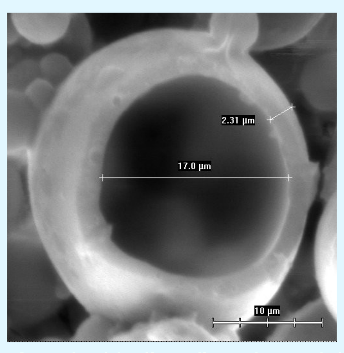

Multiple elementary EDX mapping of the polished section of heat-cured AAFA taken for six elements (Na, Al, Si, K, Ca, Fe).

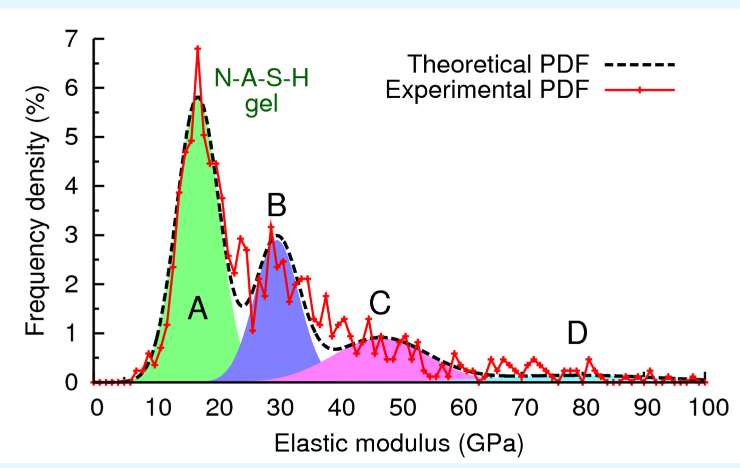

Typical efflorescence in a moisture-gradient environment.

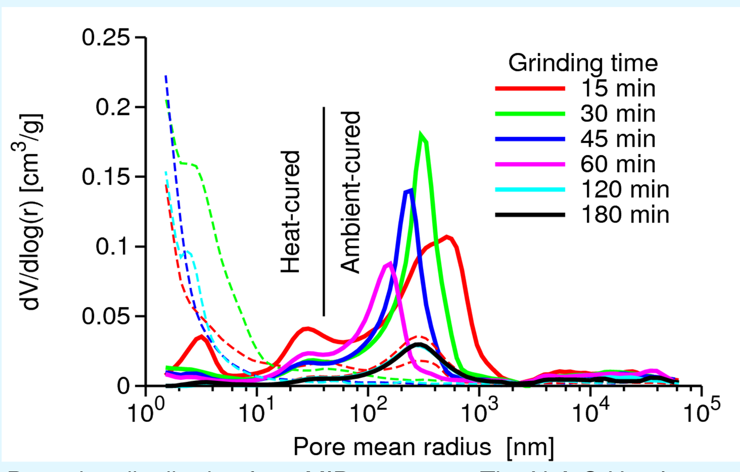
Microstructure

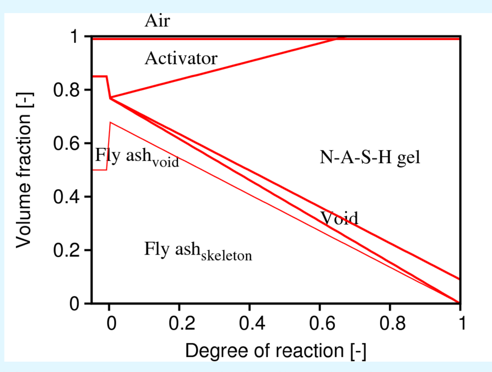

AAFA ambient-cured polished samples in secondary electron image.

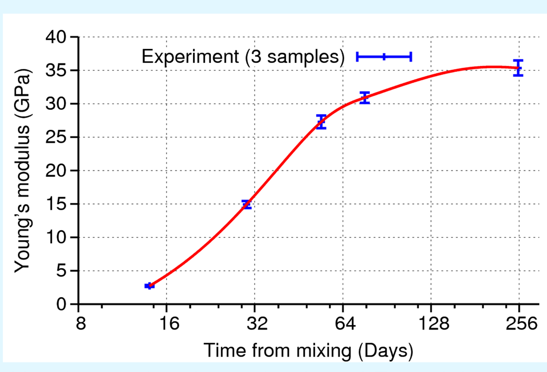

AAFA ambient-cured polished samples in backscattered secondary electron image.

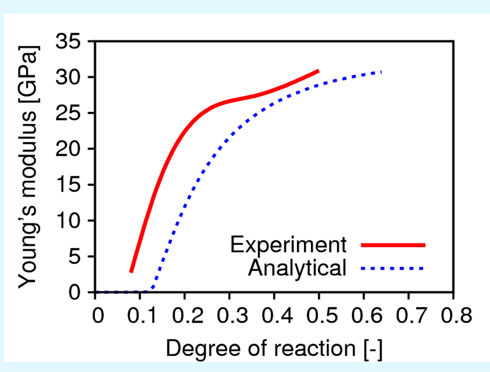

A typical hollow fly ash particle, called cenosphere.


Deconvoluted nanoindentation results in heat-cured AAFA samples. A=N-A-S-H gel, B=partly activated slag, C=nonactivated slag, D=nonactivated compact glass.


Pore size distribution from MIP on pastes. The N-A-S-H gel syneresis and aging is clearly demonstrated.


Volumetric model of alkali activation.


Nondestructive determination of E-modulus.


Micromechanical prediction of E-modulus.

Results

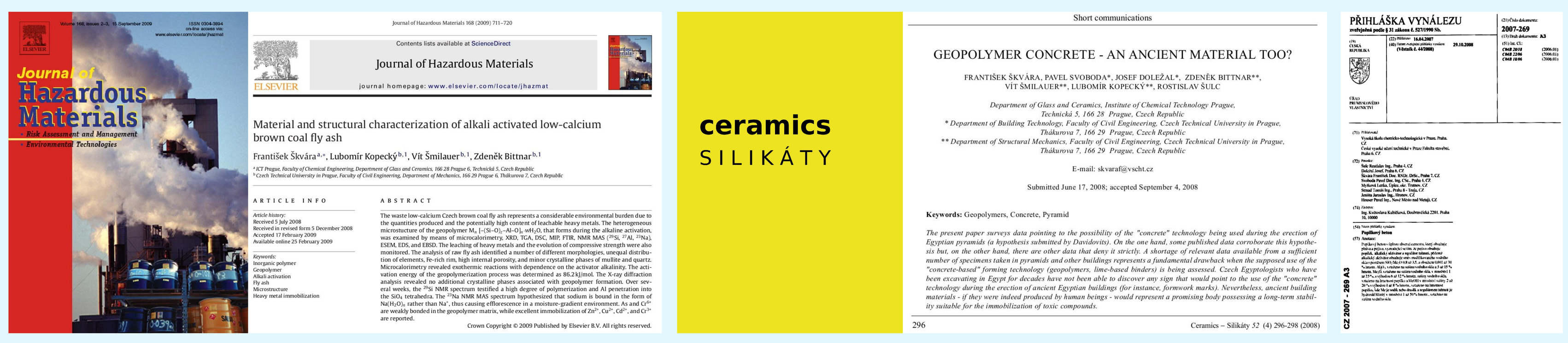

Exhibition on the application of adhesive screede made from the AAFA.


Pull-out test on the fly ash-based concrete.


Tension tests of adhesive screed on the ordinary concrete.


Casting of different samples from AAFA.


Pavement prototype after 22 weeks of exposure to weathering conditions.



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