Effect of mechanical activation of fly ash on geopolymer strength

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About our Institute

Institute of Raw Materials Preparation and Environmental Process Engineering

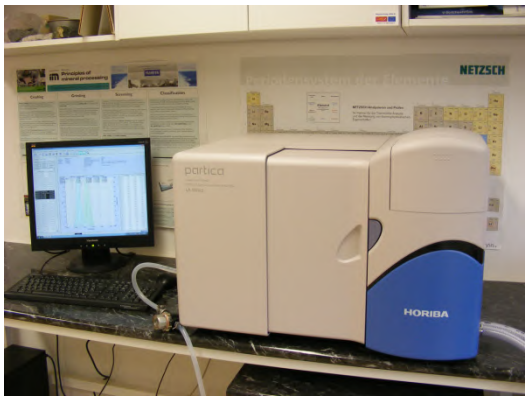
Estabilished in 1923 in Sopron

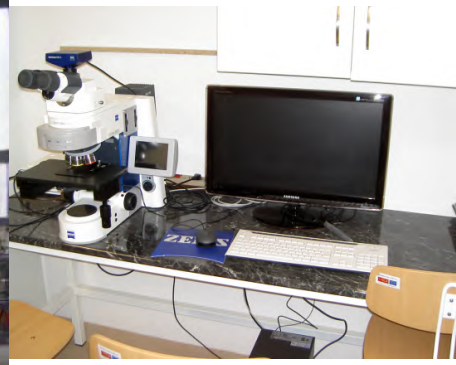
Department of Ore and Coal Preparation (1923-1960)
Department of Mineral Processing (1960-1993)
Department of Process Engineering(1993-2007)
Institute of Raw Material Preparation and Environmental Processing (2007-

Head: Prof. József Finkey (1923-1941)
Prof. Gusztáv Tarján (1941-1972)
Prof. Iván Tarján (1972-1995)
Prof. Barnabás Csőke (1995-2010)
Ass. Prof. József Bőhm (2010-2012)
Ass. Prof. József Faitli (2012-

About our Institute

Processing of raw materials and wastes (preparation) by **mechanical, physical, physical-chemical** (comminution, separation processes based on the difference of physical properties, such as density optical, magnetic, electric, thermal, surface and state properties, as well as agglomeration, mixing and homogenisation), **biological processes.**





Problem

- Power station fly ash is generated in huge amount worldwide – only in China and India about 300 million tons per year, in Europe this number is 60 million tons.
- Depositing this enormous big quantity is problematic from several points of view, e.g. fly ash dumpsite reduce the valuable fields from agricultural activity and furthermore it means an environmental risk.
- Given the EU regulations, it is crucial to develop new technologies that allow the recycling of coal fly ash into added-value products.
- The utilization of this by-product as a geopolymer additive, can effectively solve this problem due to its immobilization capacity and special characteristics.

Aim of the research

- To carry out laboratory scale experiments in order to investigate the applicability of **deposited** (decades ago) F type **fly ash** as a starting material (main component) of geopolymer.
- Three main characteristics were measured during experiments: (1) compressive strength, (2) microstructure (SEM), (3) mineral composition (XRD).
- The examination of the effect of mechanical activation of raw material on the geopolymer properties.
- Additives: glass waste, perlite, coal gangue, biomass fly ash.

Materials

Table 1. Chemical composition of deposited Class F fly ash (Berente)		Tiszaújváros	Pécs
Component	Mass concentration, %		
L.O.I.	6.80	2.85	4.21
SiO_2	53.67	59.05	54.98
Fe_2O_3	7.04	5.42	8.93
Al_2O_3	20.12	26.14	23.82
CaO	6.49	2.3	2.00
MgO	1.36	1.12	1.16
SO_3	0.95	0.25	0.12

Chemical composition of the deposited fly ash

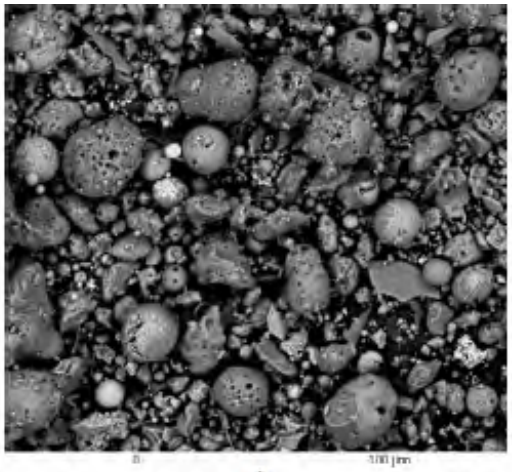
From the analysis the SiO_2/Al_2O_3 ratio was found to be
- Berente fly ash (brown coal 1) 2.67,
- Tiszaújváros fly ash (brown coal 2): 2.25,
- Pécs fly ash (black coal): 2.31.

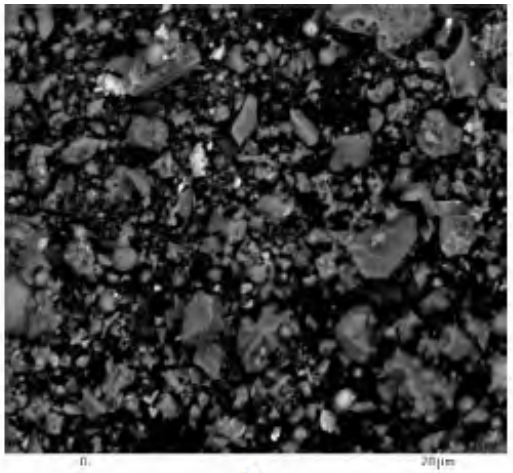
Method

- Mechanical activation – batch ball mill (10, 20, 30, 60, 120 min).
- Geopolymer production technology –
cylindrical mould (Ø50x50 mm), heat treatment at
150 ^{o}C, utilization of caustic spent liquor from alumina refinery.
- Analysis – SEM, uniaxial compressive strength, XRD.

Results

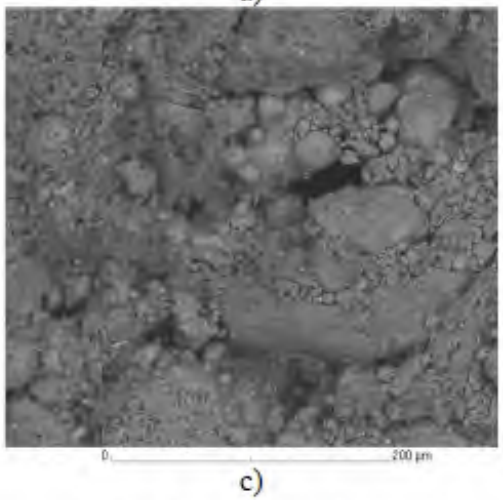
Spherical like particles

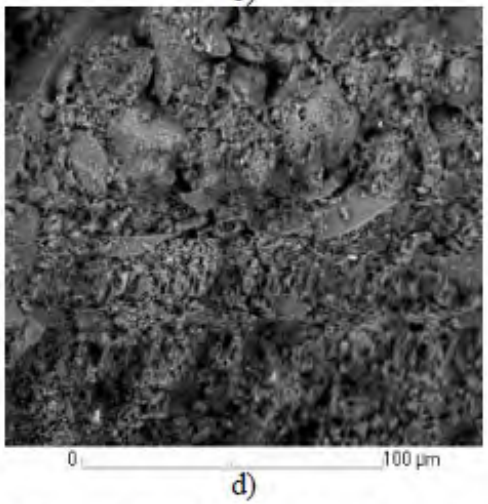




Angular shape particles

Open structure, unreacted particles, heterogenous



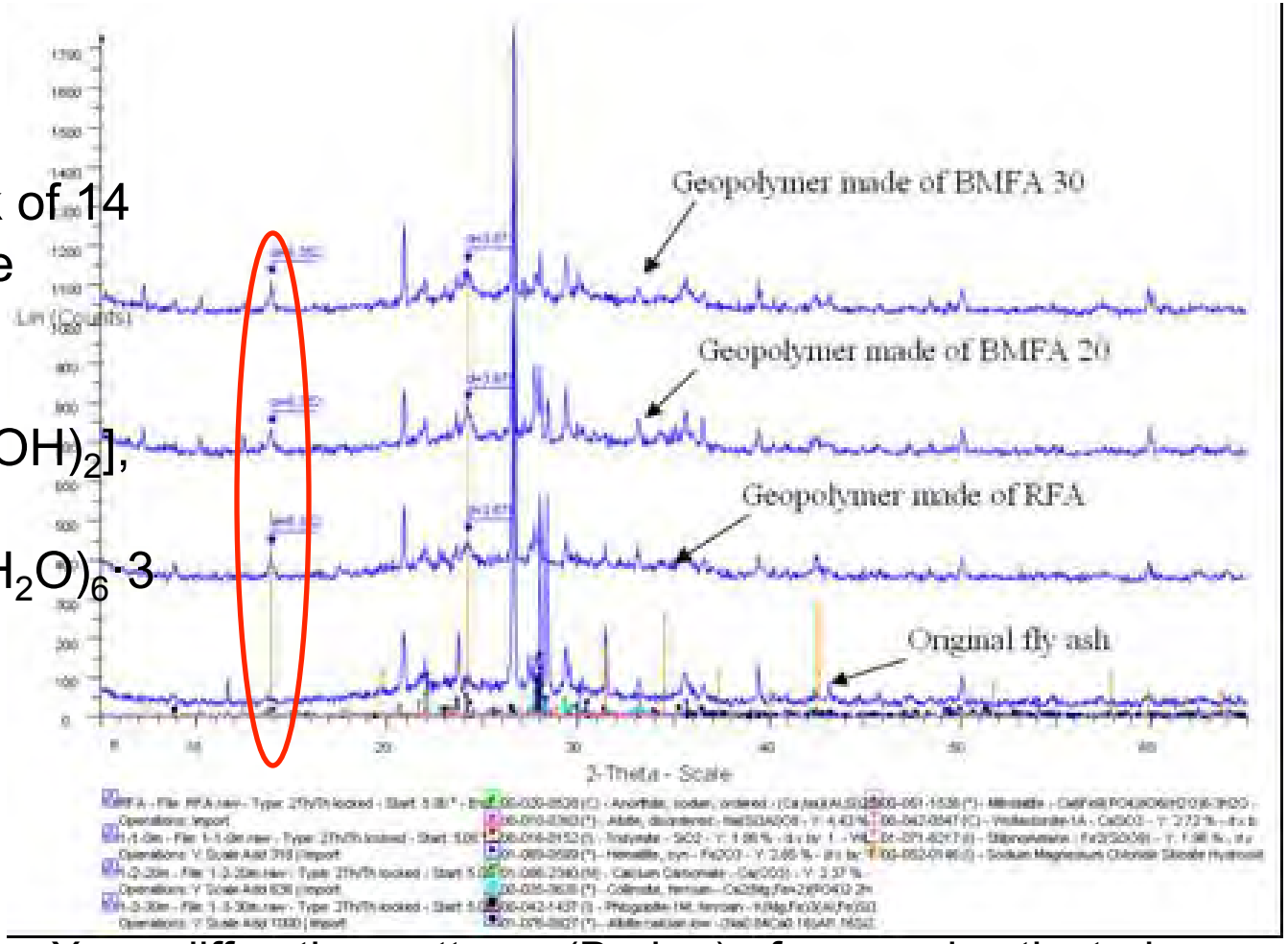


Denser, more comcact microstructure

Figure 2. SEM images of raw fly ash (a), ball milled fly ash for 20 min (b), and geopolymers made of RFA (c) and BMFA 20 (D)

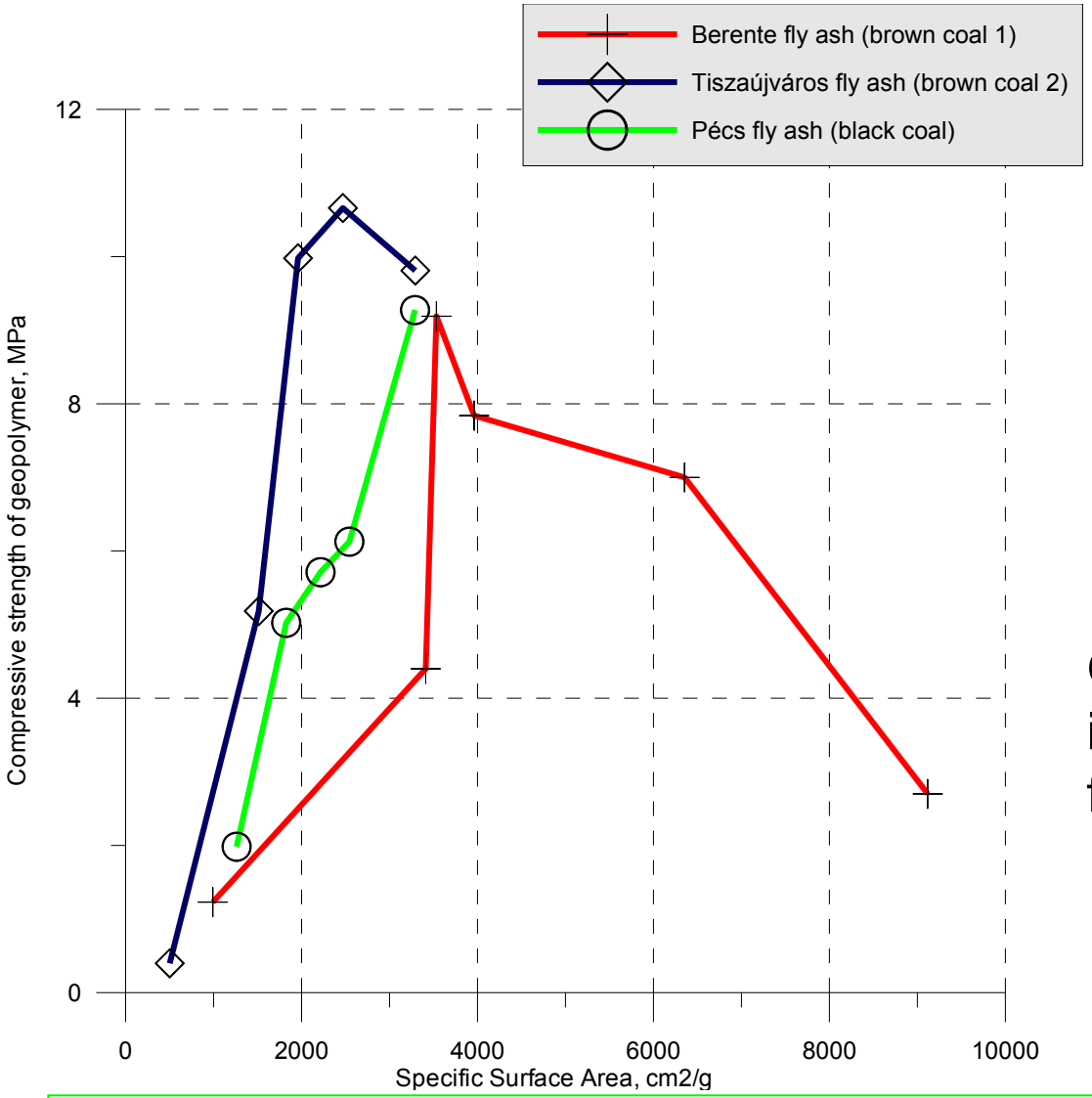
Results

New phases (peak of 14 and 24 degree) are generated: **sodalites** [$Na_8Mg_3Si_9O_{24}(Cl,OH)_2$], **mitridatite** [$Ca_6Fe_9(PO_4)_9O_6(H_2O)_6 \cdot 3H_2O$], **wollastonite-1 A** [$CaSiO_3$], **stilpnomelane** [$Fe_2(Si_3O_9)$]).



X-ray diffraction patterns (Bruker) of raw and activated fly ash based geopolymers and the initial fly ash

Results

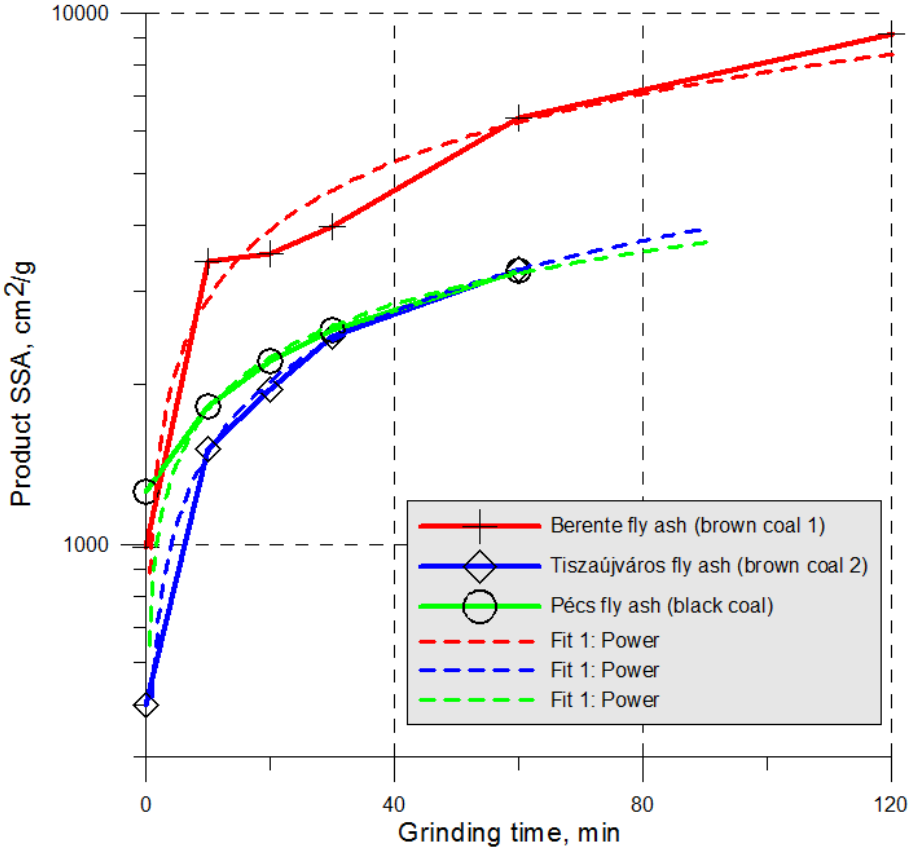


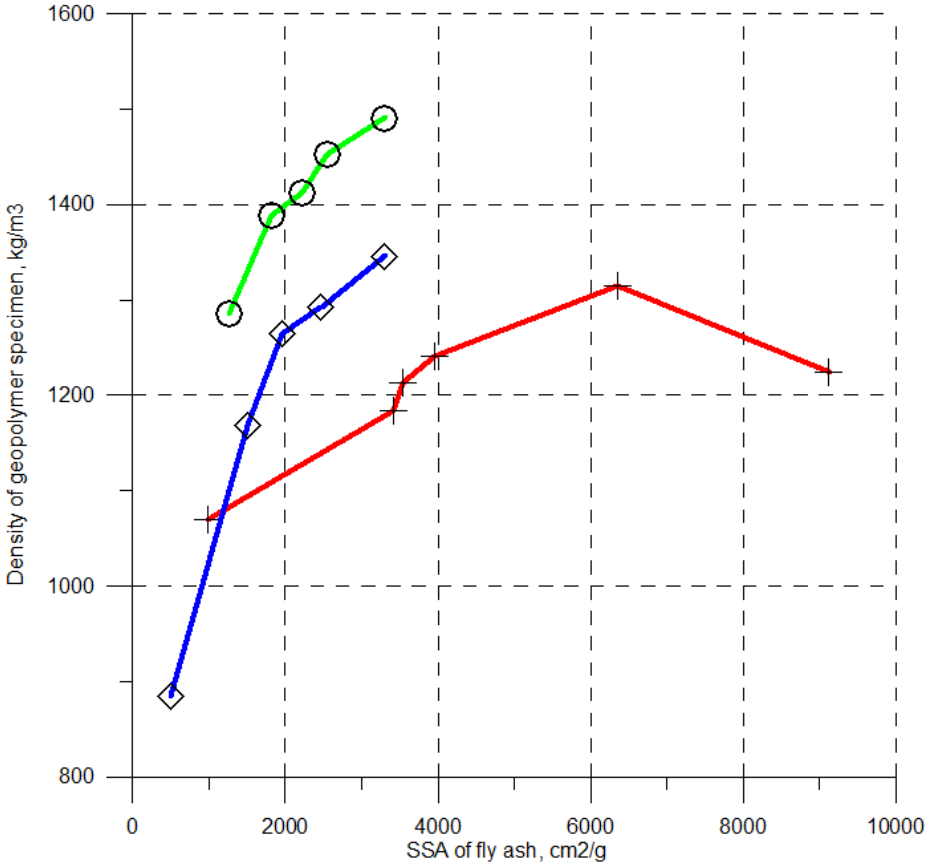
Higher specific surface area does not indicate obviously higher mechanical stability!

Optimal grinding fineness is different depending on fly ash type!

Compressive strength and specific surface area of fly ash as function of fly ash SSA

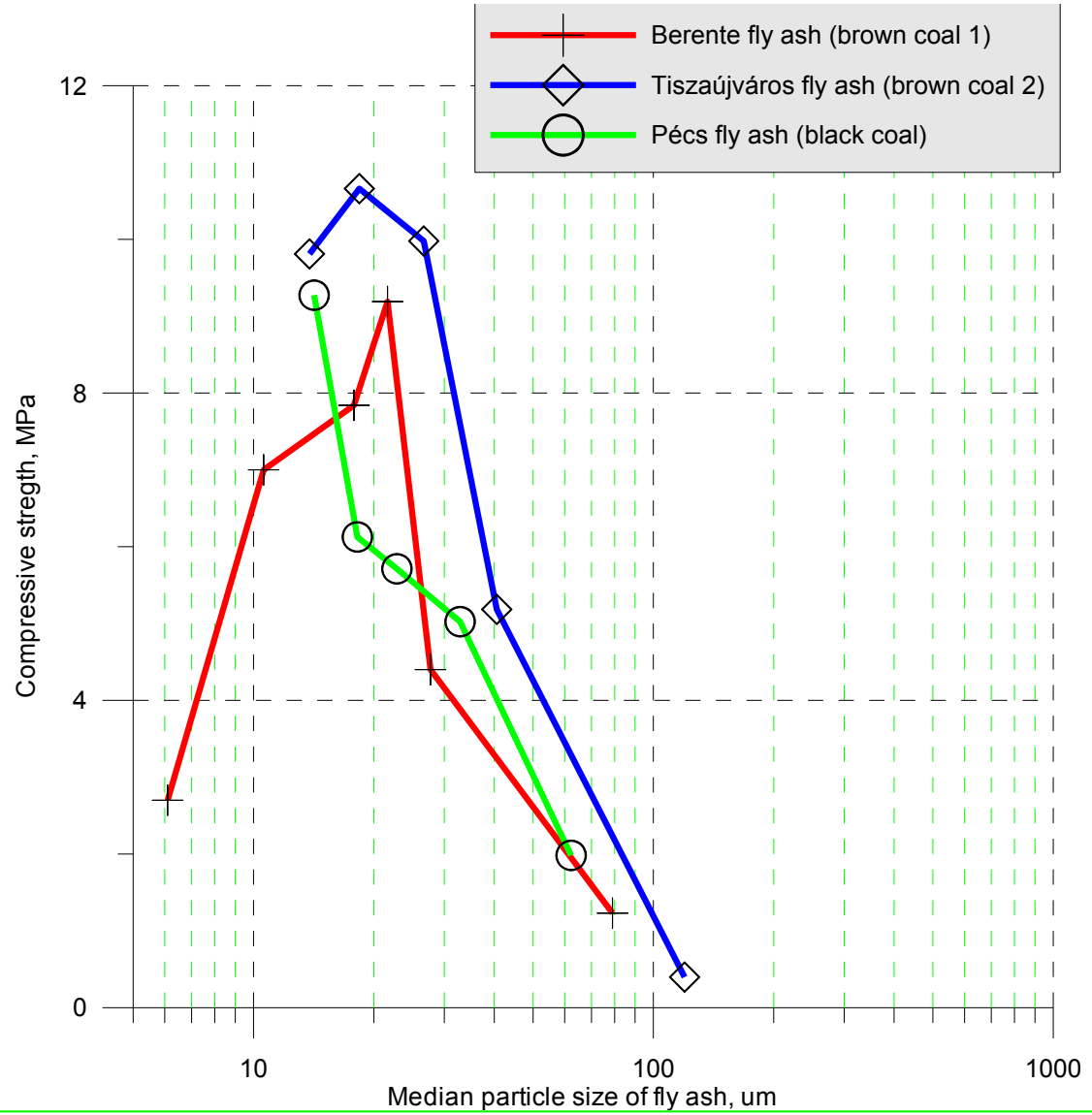
Results


10000
1000
Product SSA, cm2/g
0
40
80
120
Grinding time, min
Berente fly ash (brown coal 1)
Tiszaújváros fly ash (brown coal 2)
Pécs fly ash (black coal)
Fit 1: Power
Fit 1: Power
Fit 1: Power


1600
1400
1200
1000
800
Density of geopolymer specimen, kg/m3
0
2000
4000
6000
8000
10000
SSA of fly ash, cm2/g

Results

Optimal median size:
- brown coal: ~20 um,
- black coal: 14 um.



Conclusions

- The applied deposited Class F fly ash and spent liquor originated from alumina plant can be used for geopolymer production.
- The mechanical activation of the raw fly ash has a positive effect on the geopolymerisation, the fly ash fineness - compressive strength relation curve has maximum in case of brown coal fly ash. Black coal FA behave differently.

Conclusions and future work

- The increasing of grinding time (finer material) resulted in higher bulk density of geopolymer specimens which means denser microstructure and higher strength (until certain value).
- The geopolymerisation process using the above presented secondary raw materials did not draw down volume change or crack generation on the surface.

- Indo-Hungarian project: **Tailoring of geopolymer properties by mechanical activation** (Scientific leaders: Dr. Sanjay Kumar, Dr. Rakesh Kumar, Prof. Barnabás Csőke, Dr. Gábor Mucsi)

Thank you for your attention!

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