



SAPIENTIA
ERDÉLYI MAGYAR
TUDOMÁNYEGYETEM
KOLOZSVÁRI KAR
KÖRNYEZETTUDOMÁNY TANSZÉK



SZENT ISTVÁN EGYETEM
MEZŐGAZDASÁG- ÉS
KÖRNYEZETTUDOMÁNYI KAR
KÖRNYEZETTUDOMÁNYI INTÉZET

XIV. KÁRPÁT-MEDENCEI KÖRNYEZETTUDOMÁNYI KONFERENCIA

kiadványa

Szerkesztő:
Dr. Fülekgy György

**Szent István Egyetem
Regionális Tudástranszfer Központ
Gödöllő**

2018. április 5-7.

ISBN: 978-615-00-1645-0

Kiadó:

MAG Mezőgazdaságért Alapítvány Gödöllő

Tartalom

The Effect of Water Glass Addition on the Mechanical Properties of Fly Ash-Based Geopolymers (<i>Gábor Mucsi, Roland Szabó, Mária Ambrus, Balázs Kovács</i>)	7
A flow élmény motiváló hatása a környezeti nevelés során CP-s, SNI tanulóknál az Ókoiskola keretein belül (<i>Bacsó Gizella</i>)	13
A városi zöld infrastruktúra szerepe a környezeti nevelésben (<i>Balha Gabriella</i>)	18
Cleaning heavy metal pollution of wastewater with compost application (<i>Ramadan Benjared, György Fülek</i>)	24
Megújuló energiaforrások környezeti hatásai (<i>Bera József</i>)	30
Csapadékvíz megtisztítási hatékonyságának meghatározási módszere telepített környezetben (<i>Bosnyákovich Gabriella, Sebők András, Dálnoki Anna Boglárka, Czinkota Imre</i>)	35
A faszorok jelentősége az agrártájakban a vonuló madarak szempontjából (<i>Bozó László, Bozóné Borbáth Erna</i>)	42
Széléróziós vizsgálatok egy nyírségi garmadán (<i>Buró Botond, Tóth Csaba, Lóki József, András Bence, Négyesi Gábor</i>)	47
A szabadkai köztemetők dendroflórája (2015) (<i>Czékus Borisz, Czékus Géza</i>)	52
A császárfű (Paulownia Shan Tong) alapvető alaktani jellemzői a vegetáció első évében (<i>Czékus Borisz</i>)	57
The Bray-Mitscherlich equation approach, as a basic for an economically and environmentally sound fertilizer recommendation system for field crops in Hungary (<i>Péter Csathó</i>)	62
Evaluation of different fertilizer recommendation systems on various soils and crops in Hungary (<i>Péter Csathó, Tamás Árendás, Nándor Fodor, Tamás Németh</i>)	67
Termesztett és vadon termő fekete bodza (<i>Sambucus nigra L.</i>) elemtartalom vizsgálatai (<i>Csorba Virág, Kardos Levente</i>)	72
Sertés hígtrágya hatásának vizsgálata a növényi tömegre gyors tenyészedény kísérletben (<i>Dálnoki Anna Boglárka, Sebők András, Grósz János, Borka György, Rétháti Gabriella, Tolner László, Czinkota Imre</i>)	77
Policiklikus Aromás Szénhidrogének (PAH) anyatejben (<i>Dergez Tímea, Poór Viktória, Königné Péter Anikó</i>)	82
Faalapú biomassza hamu vizes kivonatában megkötött szén-dioxid felhasználása mikroalga termesztésben (<i>Fekete György, Aleksza László, Köles Péter, Czinkota Imre, Dálnoki Anna Boglárka, Grósz János</i>)	87
Az empátia mint a környezeti nevelés egy lehetséges eszköze (<i>Molnos Zselyke, Fetykó Kinga Gabriella</i>)	93
A napi hőingás, valamint a virágzáskori hőmérséklet statisztikai elemzése Kecskemét térségében a szilva (<i>Prunus domestica L.</i>) igényeit figyelembe véve (1961-2015) (<i>Füzi Tamás, Bozó László, Magyar Ágnes Mónika, Ladányi Márta</i>)	99
A bányászati tevékenység hatása Aknaszlatinán: egy monitoring vizsgálat előzetes eredményei (<i>Gönczy Sándor, Kurtyák Ádám, Tar Edina, Móra János</i>)	109
Izotermák szerepe a $Mn^{2+}/aq//Ca$ -bentonit/s/ rendszerben végbemenő határfelületi reakció értelmezésénél (<i>Habil Hargitai-Tóth Ágnes</i>)	115
Hosszantartó műtrágyázás hatása a talaj tulajdonságaira / Effect of long term fertilization on properties of the soil (<i>Harta István, Fülek György</i>)	121

The Effect of Water Glass Addition on the Mechanical Properties of Fly Ash-Based Geopolymers

Gábor Mucsi, Roland Szabó, Mária Ambrus, Balázs Kovács

Abstract

Due to the ever-growing consumer demand, the world is facing the challenges of the depletion of primary raw material deposits which makes the utilisation of secondary raw materials, i.e. industrial wastes and by-products, necessary for sustainable development and environmental protection. The article presents data on the examination of deposited fly ash from Tatabánya as possible raw material for geopolymerisation. With proper processing and the use of the optimised parameters, the examined fly ash is suitable for geopolymer production. The addition of the appropriate type and ratio of water glass to the activator solution can lead to enhanced mechanical properties.

Összefoglalás

Napjainkban folyamatosan növekszik a különböző elsődleges ásványi nyersanyagok iránti igény, így a fenntartható fejlődés és a környezeti fenntarthatóság elérése érdekében fontos a nagy tömegben rendelkezésre álló, másodlagos nyersanyagforrások felhasználása. A cikkben bemutatott vizsgálatokhoz tatabányai pernyét használtunk, mint lehetséges geopolimerizációs alapanyagot. A nyers pernye felhasználhatóságának vizsgálatát követően meghatároztuk a szilárd anyag és aktiváló oldat optimális arányát és az aktiváló oldat optimális összetételét: NaOH oldat koncentráció, megfelelő vízüveg típusa és aránya.

1. Introduction

Geopolymers are inorganic alumino-silicate materials synthesized at ambient or elevated temperatures. Geopolymerization occurs when amorphous alumina- or silica-rich materials, including natural minerals, calcined clays, wastes and by-products of industrial or natural origin, are mixed with highly alkaline solutions. As a result, a three-dimensional amorphous to semi-crystalline polymer structure with Si^{4+} and Al^{3+} in IV-fold coordination with oxygen is created. The advantageous properties of geopolymers include good mechanical properties, high compressive strength, low shrinkage, low thermal conductivity and acid resistance [1, 2, 3, 4].

Fly ash is an industrial waste produced by coal-fired power plants and collected during flue gas cleaning, i.e. with filter bags, electrostatic separators etc. Its main constituents are SiO_2 and Al_2O_3 and some further minor components can be CaO , Fe_2O_3 , MgO etc. [5, 6]. Approximately 40 million tons of fly ash was produced in the USA in 2015 and around 30 kt in the EU-15 in 2010 [7, 8]. Due to the high reactive alumino-silicate content, low water demand, high workability and easy availability, fly ash proved to be a suitable base material for geopolymer synthesis.

The aim of the experiments was to determine the reactivity of the raw fly ash and to examine the effects of various types and content of water glass in the activator solution on the mechanical properties of geopolymers. The appropriate ratio of fly ash and activator solution and the NaOH concentration were determined before the optimisation of water glass content.

2. Materials and methods

Landfilled brown coal fly ash from Tatabánya was used for the experiments. The moisture content of the sample was 28.80%, and the ignition loss (L.O.I.) was 0.75%. Based on the XRF analysis, the main oxidic components of fly ash were SiO_2 (46.40%), Al_2O_3 (27.40%), Fe_2O_3 (6.96%), CaO (7.04%), MgO (2.23%) and K_2O (1.65%) and TiO_2 (0.94%).

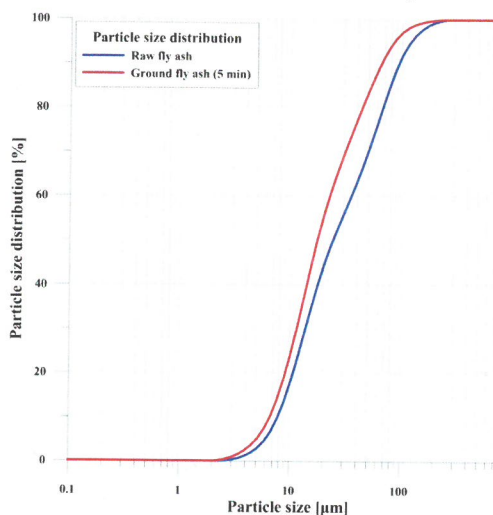


Figure 1. The particle size distributions of the fly ash samples

The particle size distribution of the raw and ground fly ash – 5 minutes – was examined with a Horiba LA950 V2 type laser particle size analyser, the “outer” specific surface area was calculated from distribution data by software using shape factor 1 (Figure 1).

The median particle size of the raw fly ash was $x_{50}=51.12 \mu\text{m}$ which decreased to $x_{50}=31.62 \mu\text{m}$ after 5 min grinding in a ball mill, while the specific surface area (SSA) of the raw fly ash increased from $1283 \text{ cm}^2/\text{g}$ to $1539 \text{ cm}^2/\text{g}$ after grinding.

Two types of water glasses were used for the experiments, the main components of which can be found in Table 1.

Table 1. The types and compositions of water glasses

Water glass	SiO_2 [%]	Na_2O [%]	K_2O [%]
Betol 39T	27.5	8.3	0.0
Betol SB	25.3	13.7	2.7

The process of geopolymer production is illustrated in the flowchart in Figure 2. First, fly ash and the activator solution was mixed in predetermined proportions and 5 specimens were prepared from each paste. Next, the moulded geopolymer paste was held under sealed conditions for 24 hours. Heat curing was carried out at 50 °C for 6 h and the specimens were left to cool down. The uniaxial compressive strength tests were carried out after a five-day holding time.

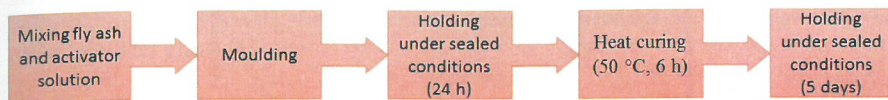


Figure 2. The simplified flowchart of geopolymer production

3. Results and discussion

3.1. The reactivity of raw fly ash

Test specimens using the raw fly ash and 6 M NaOH solution were prepared to determine the reactivity of the base material. However, the compressive strength test could not be carried out due to the inadequate mechanical stability of the specimens. Thus, the mechanical activation of the fly ash based on our previous results [9, 10] – grinding for 5 min – was necessary.

3.2. The liquid/solid ratio

For the determination of the optimal solid material and liquid activator ratio, the ground fly ash was mixed with 6 M NaOH solution in the following ratios: 50/50, 55/45, 60/40 and 65/35. Due to the low mechanical stability of the geopolymers from the 65/35 mixture, only one specimen was suitable for the compressive strength test. The average uniaxial compressive strength and specimen density values can be observed in Figure 3.

The specimen density values increased by decreasing the liquid activator quantity until reaching 1.5 g/cm³ at 45 wt%. Then the density of the specimens started to decrease.

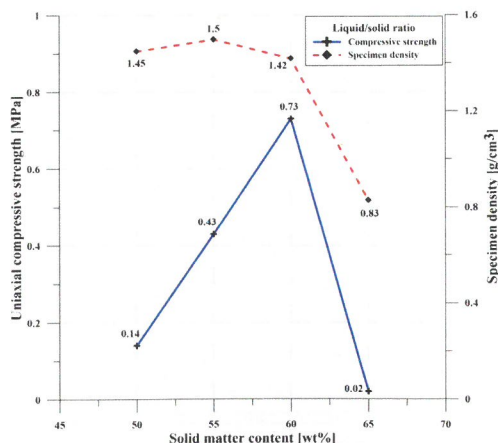


Figure 3. The effects of L/S ratio on compressive strength and specimen density

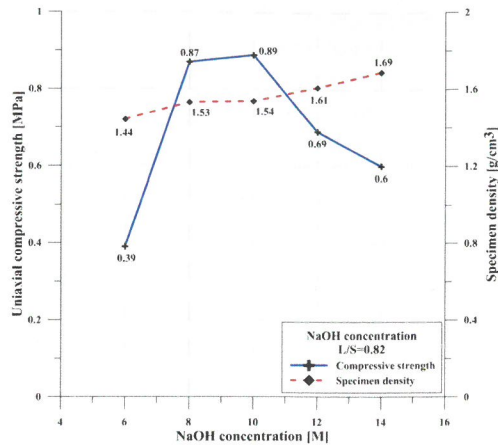


Figure 4. The effects of NaOH concentration on compressive strength and specimen density

The specimens with 60 wt% solid matter content had the highest average compressive strength, with the individual values between 0.49–1.00 MPa. Even though the compressive strength of the geopolymers with 55/45 ratio was lower, the standard deviation of the values was lower, around 4.2%.

Based on the presented data, 45 wt% activator solution and 55 wt% fly ash was used for the optimisation of the activator solution (0.82 liquid/solid ratio).

3.3. NaOH concentration

To optimise the composition of the activator solution, 45 wt% NaOH solution was added to the ground fly ash in various concentrations and the compressive strength and the density of the specimens were examined (Figure 4).

Using higher concentration sodium hydroxide resulted in higher specimen density, reaching 1.69 g/cm³ with 14 M NaOH addition.

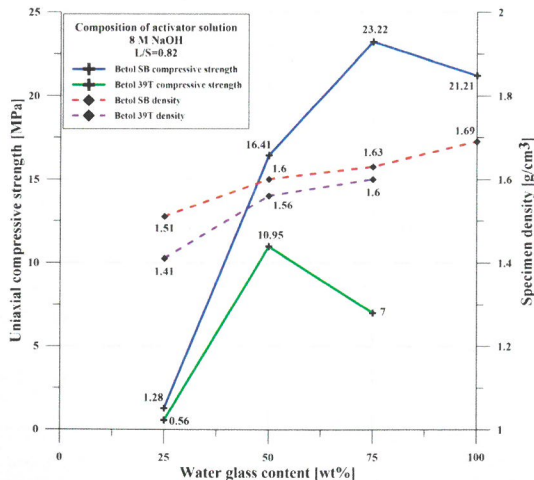


Figure 5. The effects of water glass content on compressive strength and specimen density

Increasing the sodium hydroxide concentration up to 10 M lead to higher compressive strength values, 0.87 MPa with the addition of 8 M and 0.89 MPa with the addition of 10 M NaOH. The use of higher NaOH concentration had negative effect on the compressive strength of the specimens, as the values were significantly lower in these cases.

Similarly to the previous experiment, the optimal concentration was chosen based on the standard deviation of the individual compressive strength values. As the compressive strength values were between 0.64–1.11 MPa in case of 10 M and between 0.79–0.98 MPa in case of 8 M NaOH, the latter concentration was used for the examination of the effect of water glass addition.

3.4. The effect of water glass addition

The concentration and composition of water-glass in the activating solution has a significant effect on compressive strength of geopolymers [11–13]. Betol 39T (sodium silicate) and Betol SB (sodium-potassium water glass) were added to the activator solution in 25, 50, 75 and 100 wt%. The geopolymer paste with 100 wt% Betol 39T was not suitable for moulding.

As it can be observed in Figure 5, the specimen densities increased with the addition of both water glasses.

The addition of 25 wt% Betol 39T decreased the previously achieved compressive strength, from 0.87 to 0.56 MPa. The highest average compressive strength of the Betol 39T specimens was 10.95 MPa, with the addition of 50 wt% water glass. Further Betol 39T addition had negative effect on the compressive strength of the specimens.

Higher compressive strength values could be achieved with the use of Betol SB then with Betol 39T. Even the addition of 25 wt% sodium-potassium water glass to the activator solution increased the compressive strength, exceeding 20 MPa with both 75 and 100 wt% Betol SB content.

An optimal weight percent can be observed in case of the addition of both water glasses: the use of 50 wt% Betol 39T and 75 wt% Betol SB in the activator solution leads to the highest compressive strength of the geopolymers.

4. Conclusions

Based on the experiments, the following conclusions can be drawn:

1. As the landfilled raw fly ash from Tatabánya was not suitable for geopolymerisation, the fly ash had to be mechanically activated. Thus, the reactivity of the fly ash was increased because of the decreased particle size – from $x_{50}=51.12\text{ }\mu\text{m}$ to $x_{50}=31.62\text{ }\mu\text{m}$ – and increased specific surface – from $1283\text{ cm}^2/\text{g}$ to $1539\text{ cm}^2/\text{g}$.
2. The optimal liquid/solid ratio of the ground fly ash and 6 M NaOH solution was 0.82 (55% solid matter + 45% activator solution) due to the low standard deviation of the achieved compressive strength values.
3. The increased NaOH concentration lead to enhanced compressive strength until reaching 10 M with 0.89 MPa, after which the compressive strength decreased. 8 M NaOH concentration was found to be the optimal because of the relatively low standard deviation of the individual compressive strength values.
4. Over 10 MPa average uniaxial compressive strength can be achieved by the addition of 50% Betol 39T to the activator solution. However, the use of Betol SB sodium-potassium water glass can lead to over 23 MPa compressive strength,

more than doubling the previously achieved values of the test specimens. Such high values could be achieved by the addition of 75% Betol SB to the activator solution.

Acknowledgement

The described work/article was carried out as part of the „Sustainable Raw Material Management Thematic Network – RING 2017”, EFOP-3.6.2-16-2017-00010 project in the framework of the Széchenyi2020 Program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

The authors are grateful to Ákos Debreczeni and László Köteles for the help with the strength tests and Ferenc Móricz for carrying out the XRF analysis.

References

- [1] Davidovits, J. (1991): Geopolymers: Inorganic polymeric new materials. *Journal of Thermal Analysis* 37, 1633–1656.
- [2] Provis, J.L. és Van Deventer, J.S.J. (2009): *Geopolymers – Structures, Processing, Properties and Industrial Applications* (CRC Press, Boston, 2009).
- [3] Xu, H., Van Deventer, J.S.J. (2000): The geopolymerisation of aluminosilicate minerals. *Int. J. Miner. Process.* 59, 247–266.
- [4] Duxon, P.; Fernández-Jiménez, A.; Provis, J. L.; Lukey, G. C.; Palomo, A.; Van Deventer, J. S. J. (2007): Geopolymer technology: The current state of the art. *Journal of Materials Science* 42, 2917–2933.
- [5] Bokányi L., Csöke B., Debreczeni Á., Gáspár L., Gombkötő I., Horváth R., Less Gy., Mucsi G., Molnár Z., Rácz Á. (2014): *Erőműi pernye komplex hasznosítása* (Milagrossa Kft., Miskolc, 2014).
- [6] Mucsi, G., Kumar, S., Csöke, B., Kumar, R., Molnár, Z., Rácz, Á., Máday, F., Debreczeni, Á. (2015): Control of geopolymer properties by grinding of land filled fly ash. *International Journal of Mineral Processing* 143, 50–58.
- [7] American Coal Ash Association (2016): ACAA 2015 CCP Survey Results. https://www.acaa-usa.org/Portals/9/Files/PDFs/2015-Survey-Results_Table.pdf
Downloaded: 2018.01.17.
- [8] European Coal Combustion Products Association (2011) http://www.ecoba.com/evjm.media/ccps/ECO-STAT_2010.pdf
Downloaded: 2018.01.17.
- [9] Mucsi, G., Debreczeni, Á., Máday, V., Dudok, T., Csöke, B. (2011): Development of hydraulic binder using industrial wastes (Hidraulikus kötőanyag fejlesztése ipari hulladékokból) *ÉPÍTŐANYAG* 63:(1-2.) pp. 28-32.
- [10] Mucsi, G., Molnár, Z., Kumar, S. (2014): Geopolymerisation of Mechanically Activated Lignite and Brown Coal Fly Ash. *ACTA PHYSICA POLONICA* 126: pp. 994-998.
- [11] Duxson, P., Mallicoate, S.W., Lukey, G.C., Kriven, W.M., van Deventer, J.S.J. (2007): The effect of alkali and Si/Al ratio on the development of mechanical properties of metakaolin-based geopolymers, *Colloids Surf. A Physicochem. Eng. Asp.* 292, 8–20.
- [12] Rowles, M., O'Connor, B. (2003): Chemical optimisation of the compressive strength of aluminosilicate geopolymers synthesised by sodium silicate activation of metakaolinite. *Journal of Materials Chemistry* 13, 1161–1165.
- [13] Lee, W.K.W., van Deventer, J.S.J. (2002): The effect of ionic contaminants on the early-age properties of alkali-activated fly ash-based cements. *Cement and Concrete Research* 32 (4), 577-584.