IRENA NIKOLIĆ[1], RADOMIR ZEJAK[2]
VELIMIR RADMILOVIĆ[3], DRAGOLJUB BLEČIĆ[1]
MILENA TADIC[1]

Scientific paper
UDC:504.3.056

Geopolymerization of fly ash as a possible solution for stabilization of used sandblasting grit

Geopolymers are relatively new, environmental friendly and light weight materials which form as a result of reaction of aluminosilicate materials with highly alkaline solution. They are characterised by satisfactory mechanical properties and so they are considered as a possible replacement for ordinary Portland cement in a construction. Besides, geopolymerisation technology is recognized as a possible way of immobilization of toxic waste (nuclear waste, waste water, wastes containing heavy metals).

In this paper we have investigated a possibility of immobilization of used sandblasting grit in a fly ash based geopolymers. The results have shown that geopolymerisation of fly ash with addition of used sandblasting grit is possible, but the lower compressive strength is obtained compared to the compressive strength of fly ash based geopolymer. Microstructure of synthesised geopolymers is characterised by the presence of alumosilicate gel and unreacted fly ash and Si/Al ratio determine the compressive strength of geopolymers.

Key words: *geopolymerisation, geopolymer, fly ash, sanblasting grit.*

1. INTRODUCTION

Fly ash is of coal fire by-product material from coal fired power station. The total amount of coal combustion product produced worldwide is estimated to be about 550 million tonnes, and about 68 % of total combustion products present the fly ash while about 117 millions of tonnes of fly ash is valorised into the construction industry and underground mining during 2008. year [1, 2]. Utilisation of fly ash in a construction include its use as additive in a cement industry as raw kiln feed material and as a direct cement replacement, in concrete, in the production of lightweight aggregates and lightweight blocks and road construction.

In addition of red mud, steel slag and used sandblasting grit, fly ash landfill in Pljevlja is indentified as one of major environmental problem in Montenegro. It is estimated that about 44 t/h of fly ash is produced in coal fired power station Pljevlja, [3], so its valorisation deserves a special attention. In recent years, intensively is studying geopolumerization process as an option of fly ash utilisation. Glukhovsky was first hypothesized that naturally geological transformations that occur in a aluminosilicate minerals may be the basis of structure formation process in a cementitious binder[4,5]. Later, Joseph Davidovits, [6] suggested that reaction of solid aluminosilicate minerals with strong alkali metal silicate solutions be called "geopolymerisation" and useful, environmenttally friendly, materials produced in a n such way - "geopolymer" or inorganic polymer. Raw materials for the synthesis of geopolymers can be either natural alumosilicate minerals [7,8], or wastes with high content of SiO_2 and Al_2O_3, such as fly ash and metallurgical slag [9,10]. In the past ten years geopolymers attracted much attention primarily due to good mechanical properties. The geopolymerisation mechanism has not yet been clarified and it is assumed that it consists of several steps, [11]:

- Dissolution of the solid aluminosilicate materials in the strong alkaline aqueous solution
- Formation of Si and/or Si–Al oligomers in the aqueous phase
- Polycondensation of the oligomeric species or units in the aqueous phase to form an inorganic polymeric material
- Bonding of undissolved solid particles in the final geopolymeric structure.

Besides, geopolymerisation is recognized as possible technology for immobilization of hazardous waste, [12,13]. In that sense we have investigated possibility of immobilization of used sandblasting grit through geopolymerisation process. Sandblasting grit is used in shipyard to clean dirt, corrosion, paint or other coatings from ship surface and, as a result, it contain organic and inorganic toxic components what

Author's address: [1]University of Montenegro, Faculty of Metallurgy and Technology, Podgorica, Montenegro, [2]University of Montenegro, Faculty of Civil EngineeringPodgorica, Montenegro, [3]University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia

Paper received: 12.05.2012.

may represents an important problem in the environment protection policy.

In this paper we have investigated possibility of immobilization of used sandblasting grit in the construction materials through its fixation in a fly ash based geopolymers.

2. EXPERIMENT

Fly ash used for geopolymer synthesis is supplied from coal fired power station – Pljevlja, Montenegro, and its chemical composition is given in the Table 1.

Table 1. Chemical composition of fly ash

Composition	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	CaO	Na_2O	ZnO	MgO	MnO	P_2O_5	K_2O	LOI*
%	49.45	5.23	21.77	0.66	13.34	0.46	$4.5 \cdot 10^{-3}$	1.29	0.02	0.24	1.4	4.35

*Loss on ignition

Alkali solutions were prepared by mixing of 10 $mol \cdot dm^{-3}$ NaOH solution and sodium silicate solution (Na_2O = 8.5%, SiO_2 = 28.5%, density of 1.4 kg/m^3) with a ratio water glass / NaOH of 2. Sodium hydroxide solution is obtained by dissolving of solid NaOH pallets in distilled water and sodium silicate solution was a commercial water glass supplied by Galenika Magmasil, Beograd.

Geopolymers were synthesised by mixing of fly ash or mixture of fly ash and used sandblasting grit with a alkali solution in mass ratio solid/ liquid (S/L) of 0.75, 1 and 1.25. Grit is added in a quantity of 10, 20 and 30 % of total solid content in geopolymer mixture.

Used sand blasting grit is supplied from the shipyard Bijela in Montenegro. Geopolymer paste was casted in cylindrical plastic moulds and cured in an oven at the temperature of 65^0 C for 24 h. After 24 h the moulds have been demolished and the specimens were left at the ambient temperature for a next 6 days and tested for a compressive strength. Scanning electron microscopy investigations along with EDX spectra at were done as well.

3. RESULTS AND DISCUSSION

Change of compressive strength in a function of solid to liquid ratio at different percentage used sandblasting grit is shown in the table 2.

It is evident that compressive strength of geopolymers increase with increase of solid to liquid ratio from 0.75 to 1.25. This may be explained by the decreasing of water content in a geopolymer mixture. Moreover, addition of used sand blasting grit decreases compressive strength the more the higher percentage of used sand blasting grit is added. Besides, it is visually observed that addition of used sandblasting grit increase the workability of geopolymer paste, the more the higher quantity of grit is added. This may be explained by the presence of different organic compound in a used sandblasting grit which may act on the same way as in the case of mixture of cement and water. As a result of adsorption of these compounds on the surface of fly ash repulsive forces appear what increase the paste fluidity, [14].

Table 2. Change of compressive strength in a function of solid to liquid ratio at different percentage of used sandblasting grit

Percentage of added grit	S/L		
	0.75	1	1.25
0	8	10	11
10	5.6	6.72	9.34
20	4.44	5.2	8.25
30	2.17	4.3	7.31

Results of microstructure investigation are given in the Fig. 1 and 2. Microstructure of obtained geopolymer is consisting of unreacted fly ash and gel phase (denoted with arrows) which is formed as a result of polycondensation reaction [15].

In a both cases, in pyre fly ash based geopolymer and in the case of used sandblasting grit addition, presence of geopolymer gel is evident. The final strength is dependent of the strength of gel phase in a geopolymer microstructure, and it depends of the Al /Si ratio.

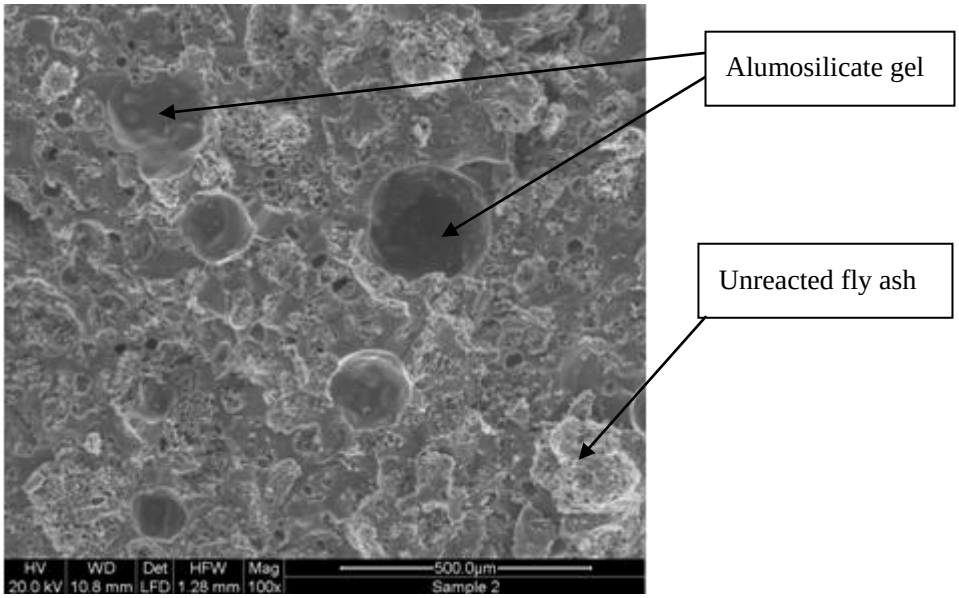

Fig.1. Microstructure of fly ash based geopolymer

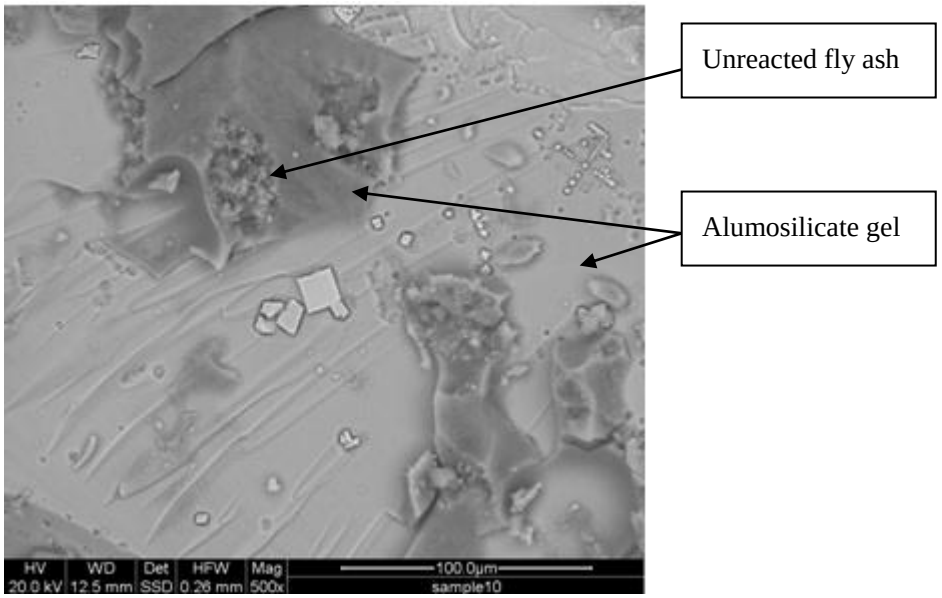

Fig.2. Microstructure of fly ash based geopolymer with addition of used sandblasting git

Table 2. Results of EDX quantification of fly ash based geopolymers with and without used sandblasting grit

	Geopolymers without used sandblasting grit	Geopolymers with used sandblasting grit
Al/Si	2.3	3.68

Previously is reported that ideal geopolymers have molar Si/Al ratios in a gel phase of 1, 2, or 3 and that the geopolymers with a Si/Al molar ratio of 2 show the best mechanical properties, [8]. The results given in the table 3. show that geopolymers prepared without of used sandblasting grit has a Al/Si molar ratio close to the ideal while those with addition of used sandblasting grit posses a significantly higher Si/Al ratio what result in decrease of compressive strength.

4. CONCLUSIONS

Investigations of possibility of immobilization of used sandblasting grit in the fly ash based geopolymers have shown that it can be integrated into the fly ash based geopolymers. Addition of used sandblasting grit into the geopolymer mixture result in a decrease of compressive strength of obtained geopolymers compared to the fly ash based geopolymer. Decrease in a compressive strength is more the higher

is percentage of added used sandblasting grit in a geopolymer mixture. In a both cases, with and without addition of used sandblasting grit in the geopolymer matrix, compressive strength increase with the increase of solid to liquid ratio.

Investigations of geopolyemers microstructure have shown that the microstructure of geopolymers, with and without used sandblasting grit, is characterrised by the presence of alumosilicate gel and unreacted fly ash. The ratio Si/Al in gel phase of fly ash based geopolymers with addition of used sandblasting grit is higher than in geopolymer without addition grit resulting in deterioration of mechanical properties of geopolymers.

Acknowledgment

The authors would like to acknowledge the ***Graz Centre for Electron Microscopy for opportunity to carry out the microstructure investigations.***

REFERENCES

[1] Ecoba, 2005, http://www.ecoba.com

[2] Ha-Won Song, Chang-Hong Lee, K.Chu Lee, V. Sarswathy, Zaštita materijal,49(2008) 3,3-10.

[3] Elaborat o procjeni uticaja na zivotnu sredinu zamjene elektrofilterskog postrojenja TE „Pljevlja“ u Pljevljima, JU Institut za razvoj i istrazivanja u oblasti zastite na radu, Maj, 2010

[4] Glukhovsky VD (1959) Soil silicates. Gosstroyizdat, Kiev, 154pp

[5] S.Muralidharan, A.K.Parande, V. Sarswathy, K. Kumar, N.Palaniswamy, Zaštita materijal, 49 (2008) 4, 3-9.

[6] J. Davidovits, Geopolymers, inorganic polymerie new materials, Journal of ThamalAnalysis, Vos 37 (1991)1633-1656.

[7] H.Xu, Geoplymerisation of alumosilicate materials, PhD Thesis, University of Melbourne, 2002.

[8] H. Xu, J. S. J. van Deventer, G. C. Lukey, Effect of Alkali Metals on the Preferential Geopolymerization of Stilbite/Kaolinite Mixtures, *Ind. Eng. Chem. Res.* 2001, *40*, 3749-3756

[9] I. Maragkos, I. P. Giannopoulou, D. Panias, Synthesis of ferronickel slag-based geopolymers, Minerals Engineering 22 (2009) 196–203

[10] J. G. S. van Jaarsveld and J. S. J. van Deventer.Effect of the Alkali Metal Activator on the Properties of Fly Ash-Based Geopolymers, *Ind. Eng. Chem. Res.* 1999, *38*, 3932-3941

[11] D. Panias, I.P. Giannopoulou,T. Perraki, Effect of synthesis parameters on the mechanical properties of fly ash-based geopolymers, Colloids and Surfaces A: Physicochem. Eng. Aspects 301 (2007) 246–254.

[12] J.G.S. Van Jaarsvald , J. S. J. Van Deventer, L. Lorenzen, “Factors Affecting the immobilization of Metals in Depolymerised Fly ash”, Metallurgical and materials transactions, Vol.29 B, 1998, p. 283-291

[13] J.Marku, The incorporation of fly ash as supplementary cementing material in concrete, Zaštita materijala, 51 (2010) 3, 159-165.

[14] S. Rajendran, T.S. Muthumegala, M. Pandiarajan, P. Nithya Devi,A. Krishnaveni, J. Jeyasundari, B. Narayana Samy, N. Hajara Beevi, Zaštita materijala, 52 (2011) 3, 85-90.

[15] M. Criado, A. Palomo, A. Fernández-Jiménez, P. F. G. Banfill, Alkali activated fly ash: effect of admixtures on paste rheology, Rheol Acta (2009) 48: 447–455.

IZVOD

GEOPOLIMERIZACIJA LETEĆEG PEPELA KAO MOGUĆEG REŠENJA ZA STABILIZACIJU KADA SE KORISTI ZA PESKARENJE

Geopolimeri su relativno novi, ekološki i lagani materijali, koji se formiraju kao rezultat reakcije aluminosilikatne materijale sa visoko alkalnim rastvorima. Odlikuju ih zadovoljavajuće mehaničke karakteristike, tako da se smatraju kao moguća zamena za obične Portland cemente pri izgradnji. Osim toga, tehnologija geopolimerisanja je prepoznata kao mogući način imobilizacije toksičnog otpada (nuklearni otpad, otpadne vode, otpadi koji sadrže teške metale).

U ovom radu je istraživana mogućnost imobilizacije kada se pri peskiranju koristi granulacija samo letećeg pepela na bazi geopolimera. Rezultati su pokazali da geopolimerizacija letećeg pepela određene granulacije koda se koristi pri peskiranje je moguća, ali se dobija niža čvrstoća u odnosu na čvrstoću od letećeg pepela na bazi geopolimera. Mikrostruktura sintetizovanih geopolimera karakteriše prisustvo gela alumosilicijuma i nereaktivnog letećeg pepela a Si / Al odnos određuju čvrstoću geopolimera.

Ključne reči: *geopolimerizacija, geopolimer, leteći pepeo, peskarenje.*

Rad primljen: 12.05.2012.

Originalni naučni rad