UNIVERSITY OF BELGRADE
TECHNICAL FACULTY IN BOR
CHAMBER OF COMMERCE AND
INDUSTRY OF SERBIA

PROCEEDINGS

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DEVELOPMENT AND MECHANICAL PROPERTIES OF THE PELLETIZED FLY ASH

Sonja Milićević [1, #], Sanja Martinović [2], Vladimir Jovanović [1], Milica Vlahović [2], Ndue Kanari [3], Ana Popović [1], Marija Kojić [2]

[1]Institute for Technology of Nuclear and Other Mineral Raw Materials, Belgrade, Serbia

[2]University of Belgrade, Institute of Chemistry, Technology and Metallurgy, Belgrade, Serbia

[3]Université de Lorraine, UMR 7359 CNRS, CREGU, GeoRessources Laboratory, 2, rue du doyen Roubault, BP 10162, 54505 Vandoeuvre-lès-Nancy, France

ABSTRACT – This paper covers results of pelletizing fly ash in order to obtain pellets, with the satisfied mechanical properties, that can be used in wastewater treatments. Serbian fly ash from "Nikola Tesla" power plant was used as a low cost sorbent. Fly ash was subjected to the elementary and XRD analysis. Portland cement was used as pelletizing agent along with the plastification agent. Mechanical properties of pellets were investigated using different methods such as: pressure resistance, impact resistance, resistance to abrasion and disintegration in water. Best results were obtained with addition of 10 % of cement along with the plasticizer.

Key words: fly ash, pellets, mechanical properties.

INTRODUCTION

Recent investigations are focused on possibility of waste utilization as potential adsorbents in wastewater treatments. Industrial by-products and wastes are almost zero-cost materials and at the same time their utilization could contribute to the solution of their management problem improving the material efficiency within the several industrial activities.

Fly ash has potential application in wastewater treatment because of its major chemical components (alumina, silica, ferric oxide, calcium oxide, magnesium oxide and carbon), and its physical properties such as porosity, particle size distribution and surface area. Besides, the alkaline nature of fly ash makes it a good neutralizing agent [1, 2]. Namely, fly ash as a potential hazardous solid waste produced like a by-product in power plants worldwide in million tonnes has attracted researches

[#] corresponding author: s.milicevic@itnms.ac.rs

interest for years. Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify rapidly while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 μm to 300 μm. Therefore, the hydraulic properties of fly ash are the one that present major obstacle for its application in wastewater treatments.

The problem of micronized fly ash particles that are not useful in wastewater treatments can be overcome through the agglomeration process such as pelletization. Pelletization is a form of tumble growth agglomeration, whereby material fines are "grown" through a tumbling motion and the addition of water or a binding agent [3]. This process is a non-pressure method of agglomeration that allows production of new materials and use of waste resources with significant environmental and economic impact.

This paper is focused on processing and valorization of industrial waste - fly ash in order to obtain new adsorption material with good mechanical properties and removing capacity for heavy metals from acid mine wastewaters.

EXPERIMENTAL

Materials

Fly ash originates from power plant Nikola Tesla (Tent B) and the chemical composition is presented in Table 1.

Table 1. Chemical composition of the fly ash

Content (%)							
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2
47.80	30.53	5.47	8.69	2.29	1.49	0.25	1.02
Cd	Pb	Zn	Cu	Cr	Ni	Mn	IL*
0.005	0.04	0.021	0.005	0.022	0.03	0.045	1.45

IL * - Ignition lost

Chemical composition places the investigated fly ash to the class F that is characterized with pozzolanic properties.

The mineralogical composition of fly ash was primarily quartz with small amounts of mullite and plagioclase as determined by X-ray powder diffraction analysis (Philips, PW-1710).

Particle size distribution (Figure 1), determined using laser diffraction method (Helos (H1597) & Sucell R4, Sympatec GmbH) show the major size fraction mass content (60 %) of the class below 100 μm.

Cement used in these investigations belong to group of Portland cement and is produced by the Lafarge (PC 42.5R Lafarge).

Plasticizer is applied as chemical additive with a purpose to absorb on the cement particles and build the network of the cement particles. Plasticizer used in this paper belongs to the group of the highly efficient superplasticizer (hyperplasticizer) Cementol Hiperplast 463, produced by the TKK, Slovenia. The effect of the plasticizer depends, mainly, on the type and the amount of the cement. Frame dose of the plasticizer is 0.2 - 1.5 kg plasticizer / 100 kg cement. The mixing time, after the addition of the plasticizer should be at least 1 min, where the optimal time is 3 min.

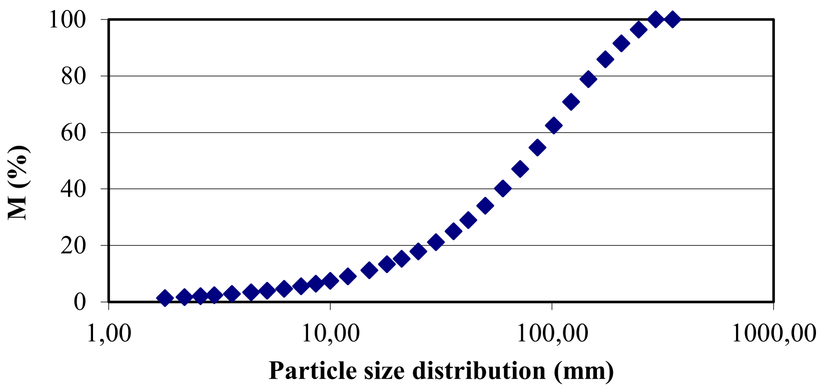

Figure 1. Particle size distribution of the fly ash

Table 2. Chemical composition of the Portland cement

Content (%)							
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5
21.10	5.42	2.38	63.18	2.35	0.74	0.23	0.12
$SO_3 < 4$ %	Cl	Na_2O_{eq}	ZnO	Mn_2O_3	SrO	TiO_2	/
3.56	0.0386	0.72	0.038	0.11	0.099	0.245	/

Pelletization

Fly ash pelletizing was conducted on "Ünal" disc pelletizer with vibratory feeder, (plate diameter 40 cm, edge height 10 cm, plate inclination angle of 50 °, rotary speed 15 rpm).

The initial samples of fly ashe and cement were homogenized. This is a precondition that must be met in order to obtain pellets of uniform composition during pelletizing. Fly ash is homogenized with the required amount of cement as a binder, without adding any water. After that, the homogenized samples are by vibratory feeder continuously fed on to the pelletizing plate, where the necessary amount of water is added using sprayers. During pelletizing experiments, in some samples, precisely defined amount of plasticizer was added, also. The plate inclination angle (50 °) and the number of revolutions (15 rpm) were constant, while the quantity of the binder varied.

Four composite samples were formed by mixing Fly ash, cement as binder and plasticizer with the Fly ash to cement mass ratio presented in Table 3.

Table 3. Content of the materials used for the production of pellets

Mark	Fly ash	Cement	Plasticizer
P10p	90 %	10 %	0.15 ml
P10	90 %	10 %	/
P5p	95 %	5 %	0.07 ml
P5	95 %	5 %	/

Number next to the letter P indicates the percentage of the cement in the sample and the presence of letter ''p'' in subscript implies the addition of the plasticizer.

Formed pellets were stored for 72 h at the 90 % moisture saturated atmosphere and then dried at 40 °C .

RESULTS AND DISCUSSION

After drying process, pellets were sieved and four different fraction sizes were obtained, as presented in Figure 2.

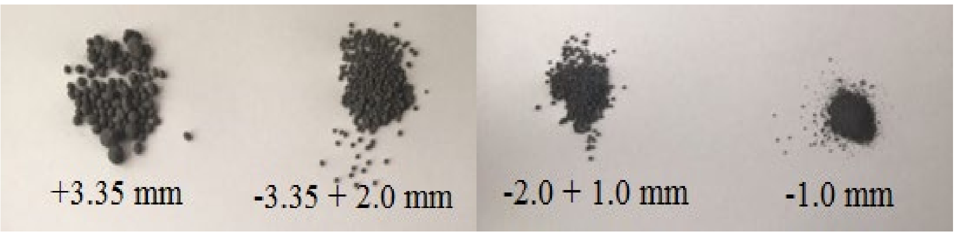

Figure 2. Different fraction sizes of the obtained pellets

Particle size distribution, presented in Figure 3, indicate the largest presence (41 %) of the class - 2.0 + 1.0 mm. This particle size along with the class of - 3.35 + 2.0 mm (17 %) and class of - 7.0 + 3.35 mm (24 %) are the preferred size of the pellets for their application in the dynamic (column) systems. The percentage of the undesirable class of - 1.0 mm below 20 % is a very good result.

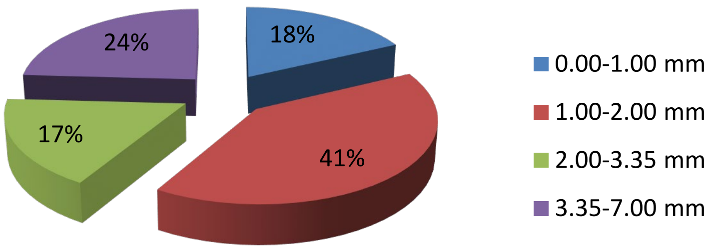

Figure 3. Particle size distributions of the pellets

The purpose of fly ash pelletization, in this paper, is to obtain the material that is more suitable for the application in the wastewater treatments than the parenting one (micronized fly ash). In generally, the pellets are produces to improve the hydraulic properties of the fly ash. However, from the transport and handling point of view, there are certain mechanical properties that pellets need to satisfy. Tests for pellet mechanical properties include: impact resistance, compressive strength, abrasion resistance and the time required for the pellet to disintegrate completely in water.

Impact resistance is tested by dropping a 100 g pellet sample 25 times from the height of 457 mm on to a 9 mm thick steel plate, after which the sample is sieved on a corresponding screen, whereat the mass of screen undersize should not exceed 5 % (more rarely 10 %) of the total mass of the sample [4]. Obtained results are presented in Table 4.

Table 4. Dependence of the pellets impact resistant on binder content

	1.0 - 2.0 mm	2.0 - 3.35 mm	3.35 - 7.0 mm
	%		
P10p	10.5	9.3	9.2
P10	19.3	16.1	14.6
P5p	65.8	47.1	34.6
P5	81.1	78.3	75.4

According to the results, the dosage of the binder and the addition of the plasticizer, both, highly influence this mechanical property of the pellets. Only pellets with the 10 % of cement and addition of plasticizer meet the requested demand for this mechanical property.

Compressive strength is tested on 10 pellet samples using a standard laboratory hydraulic press in order to determine the maximum pressure that the pellet can withstand without breaking. Pellets should be able to withstand a minimum of 0.5 kg/pellet, which is considered as satisfactory for further handling [4]. Obtained results are presented in Table 5.

Table 5. Dependence of the pellets compressive strength on binder content

	1.0 - 2.0 mm	2.0 - 3.35 mm	3.35 - 7.0 mm
	kg/pellet		
P10p	0.45	0.60	1.12
P10	0.32	0.51	0.73
P5p	0.15	0.32	0.45
P5	0.09	0.15	0.21

From the results in Table 5 it's obvious that the dosage of the cement highly influences this property. Pellets with 10 % of cement, regardless the addition of plasticizer, mostly meet the requested demand, and the compressive strength increases with increasing the particle size.

Pellet abrasion resistance is tested by sieving a 100 g pellet sample on a laboratory mechanical device, i.e., a corresponding screen, for a period of 5 min. After that it was possible to determine that the mass fraction of screen undersize should not exceed 5 % of the total mass of the sample [4]. Obtained results are presented in Table 6.

Table 6. Dependence of the pellets abrasion resistance on the binder content

	1.0 - 2.0 mm	2.0 - 3.35 mm	3.35 - 7.0 mm
P10p	0.52	3.13	3.17
P10	1.59	4.86	4.98
P5p	2.65	17.5	11.95
P5	5.2	21.3	25.4

Pellets with 10 % of cement, regardless the addition of plasticizer and particle size distribution meet the requested demands.

The disintegration of pellet in water is tested by immersing three pellet samples from each group into the water, at room temperature and measuring the time required for the pellet to completely disintegrate in water. Obtained results are presented in Table 7.

Table 7. Average time required for pellets to disintegrate in water depending on binder dosage

	1.0 - 2.0 mm	2.0 - 3.35 mm	3.35 - 7.0 mm
		h	
P10p	0.52	3.13	3.17
P10	1.59	4.86	4.98
P5p	2.65	17.5	11.95
P5	5.2	21.3	25.4

All investigated pellets, regardless the cement dosage, addition of plasticizer and the particle size distribution meet this demand.

CONCLUSION

Fly ash can be efficiently pelletized using cement as binder. Under the investigated pelletizing conditions, more than 80 % of the obtained pellets are suitable for the application in continuous systems, from the particle size distribution point of view. For the production of the pellets with the satisfying mechanical properties, required amount of the cement as binder is 10 %. The dose of the plasticizer, up to 3 % in relation to the amount of the cement, additionally improves the mechanical properties, especially impact resistance.

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