STUDIA UNIVERSITATIS BABES-BOLYAI, CHEMIA, LIV, 1, 2009

Dedicated to Professor Liviu Literat, at his 80th anniversary

POWER PLANTS ASHES RECOVERY IN ECO-FRIENDLY MORTAR COMPOSITIONS

LÁSZLÓ SZÉLL[a], VALENTINA CETEAN[b], TÓTH ANIKÓ[a], GAGEA LUCIA[c], ROMAN CECILIA[d], ROMAN MARIUS[d], GOG ADRIANA[d]

ABSTRACT. The paper treats the possibilities to recover the wastes resulted by coal combustion in power plants. This issue is in the researchers attention because the power plant's ashes represents the main waste in almost all European countries and the coal combustion will remain the most important source of energy. The greenhouse gas and the ashes have a huge impact on environment and the living species. In the experimental work the properties of five different mortars, realized with different proportion of ash were compared.

Keywords: *fly ash, concrete, mortar*

INTRODUCTION

The main reason for the ash use is not only the low price, but also the technical and qualitative benefits brought to the products. Due to its puzzolanic activity the ash combine with calcium hydroxide resulted from cement hydration giving birth in this way to cementitious materials which harden in time and have similar properties with the cement hydration products [1-3]. Through this activity is reduced the calcium hydroxide quantity in concrete which can leach in time by water providing cracks and voids. Thereby, the porosity and permeability of the concrete are reduced and the freeze-thaw resistance is increased, with other words the concrete is more durable.

[a] *S.C. Procema Cercetare S.R.L., Punct de lucru Cluj-Napoca, Str. Beiuşului, Nr. 1, RO-400394 Cluj-Napoca, Romania, procema.cluj@clicknet.ro*

[b] *S.C. Procema Geologi S.R.L., B-dul Preciziei, Nr.6, RO-062203 Bucureşti, Romania, procema.geologi@clicknet.ro*

[c] *Universitatea Babeş-Bolyai, Facultatea de Chimie şi Inginerie Chimică, Str. Kogălniceanu, Nr. 1, RO-400084 Cluj-Napoca,Romania, gagea@chem.ubbcluj.ro*

[d] *INCDO-INOE2000 filiala ICIA, str Donath, Nr. 67, RO-400293 Cluj-Napoca, Romania, icia@icia.ro*

Ashes fill in the minute voids that no other part of the mix can fill, thus creating a denser and less absorptive concrete with improved mechanical features. On short term mechanical strengths are lower than plain concrete, after 28 days they equalized and after a long period of hydration products with ashes present 15-20% higher mechanical strength than classic concrete [4-6].

Ashes use – recovered wastes – reduces the natural resources use. They also reduces the energy-intensive production of other concrete ingredients, leading to energy saving and "greenhouse gas" emission decrease. Replacing one tone of cement with fly ash it would save enough electricity to power an average home for 24 days, and reduce carbon dioxide emissions equal to a two months use of an automobile.

RESULTS AND DISCUSSIONS

The setting time (SR EN 196-3:2006) and the workability (SR EN 1015-9:2002) were determined on the fresh mortar. The results are presented in Figures 1 and 2.

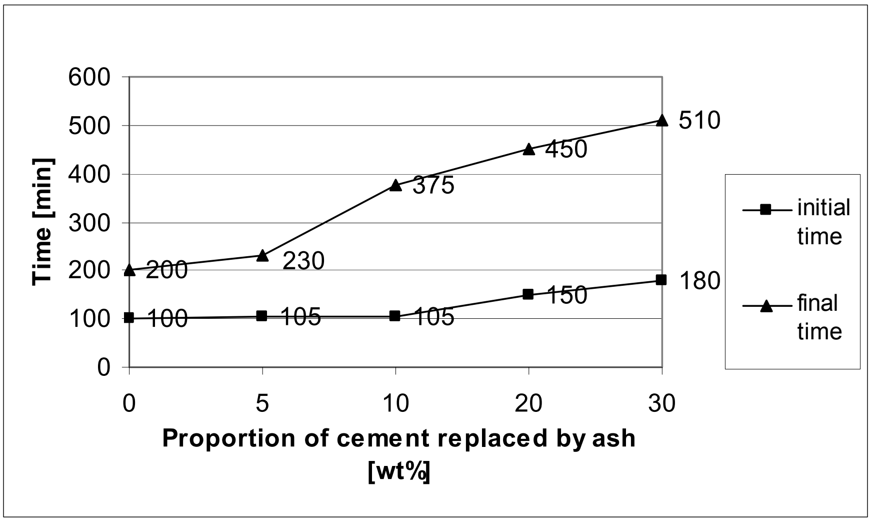

Figure 1. Variation of setting time in function of proportion of cement replaced by ash.

After 28 days of hardening in standard conditions (5 days in moulds at 20°C and 90% humidity; 2 days without moulds at 20°C and 90% humidity; 21 days without moulds at 20°C and 65% humidity) the density and water absorption of the mortars were determined using the methods indicated in SR EN 1015-10:2002 and SR EN 1015-18:2003.

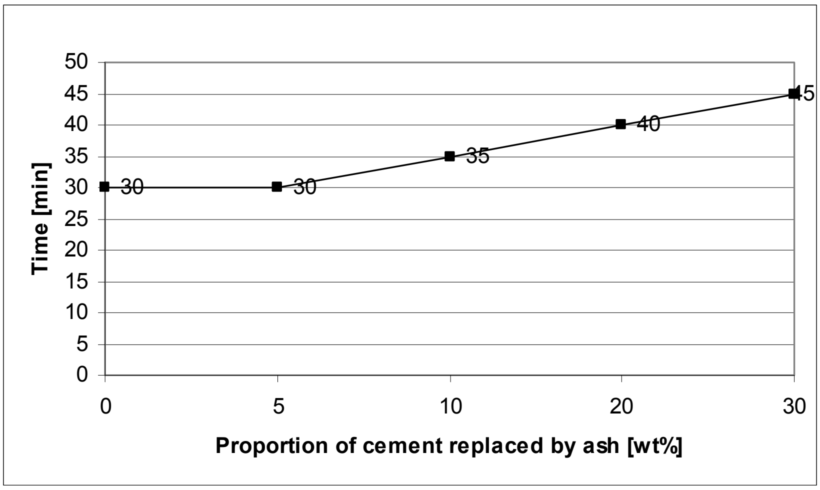

Figure 2. Variation of workability in function of proportion of cement replaced by ash.

The results are shown in the Figures 3 and 4.

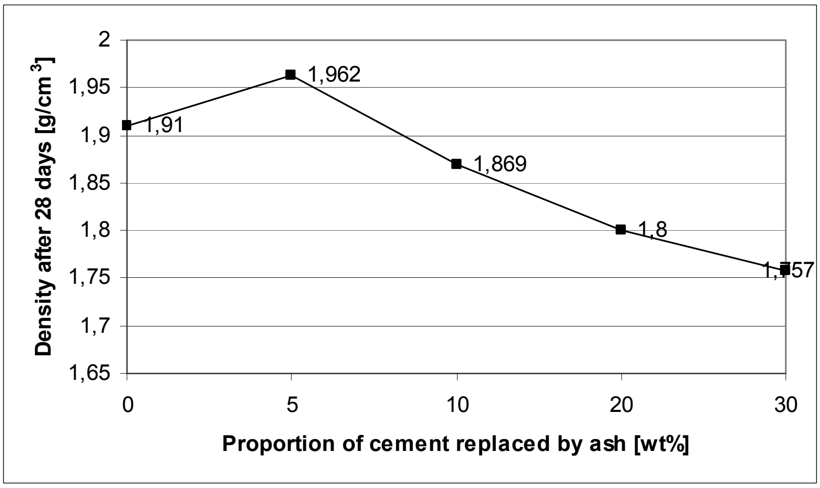

Figure 3. Density variation in function of cement replaced by ash.

The flexural and compressive strength of the compositions were determined after 28 days of hardening using the method indicated in SR EN 196-1:2006. In Figure 5 is presented the evolution of the strength in function of proportion of cement replaced by ash.

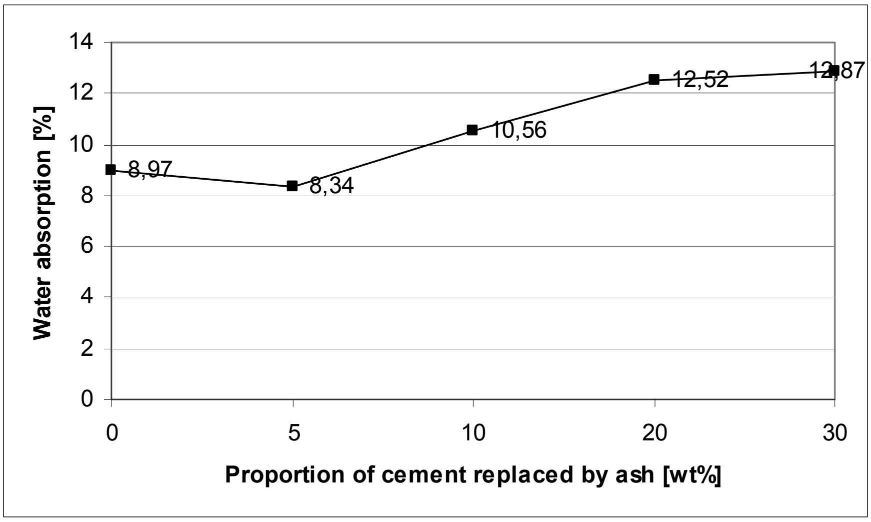

Figure 4. Water absorption variation in function of cement replaced by ash.

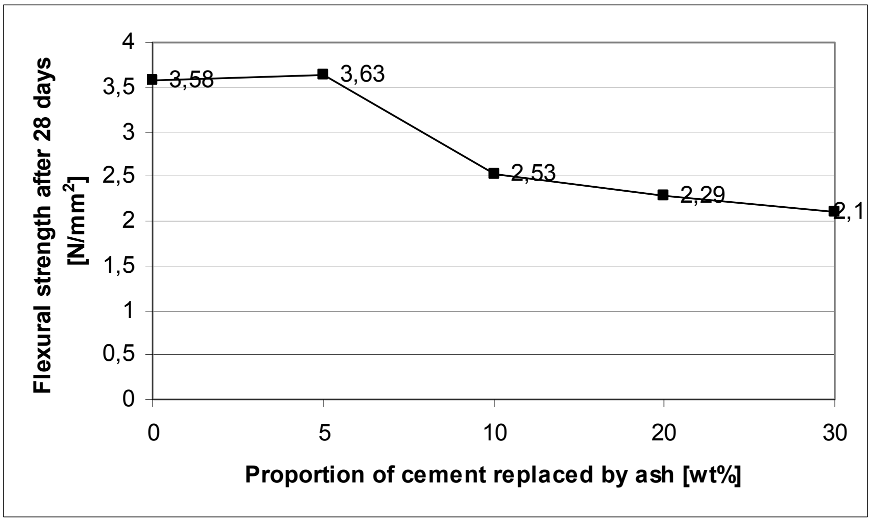

Figure 5. Flexural strength variation in function of proportion of cement replaced by ash.

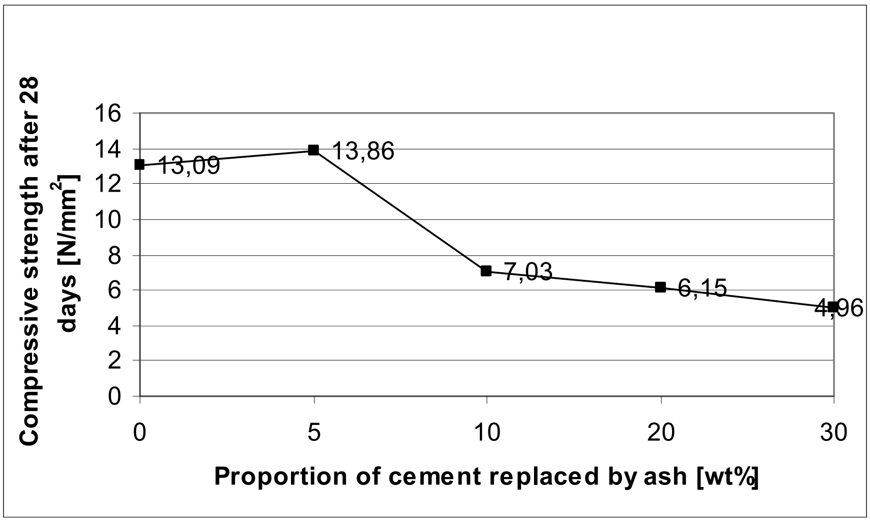

Figure 6. Compressive strength variation in function of proportion of cement replaced by ash.

It is a known fact that the mechanical strength of the mortars and concretes with ash content is lower after 28 days and a beneficial effect it is observed only after 56 or 91 days. To demonstrate the evolution of the strength, mechanical tests were repeated after 56 days (Figure 7 and 8).

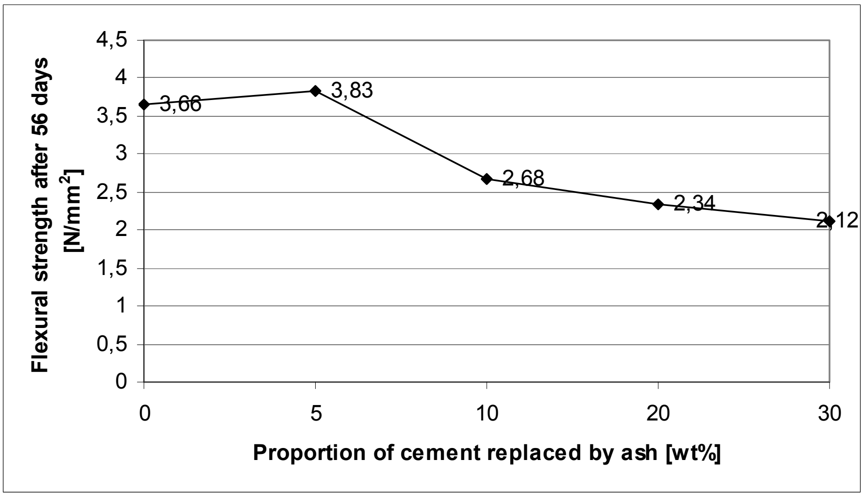

Figure 7. Flexural strength variation in function of proportion of cement replaced by ash.

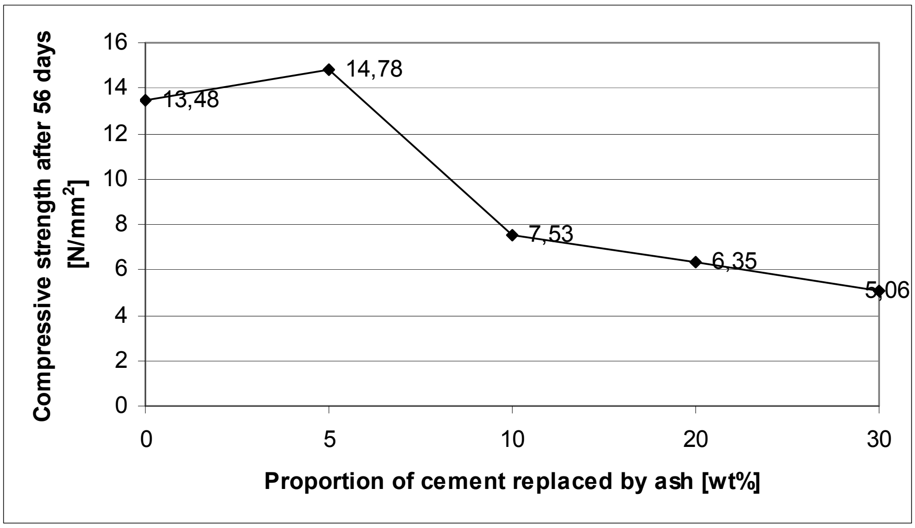

Figure 8. Compressive strength variation in function of proportion of cement replaced by ash.

From the figures presented above it can be concluded that it is possible to use ashes in mortar compositions, respectively a part of the cement can be replaced by ashes. The replacement of cement in proportion of 5, 10, 20 and 30 wt% was experimented (composition 2, 3, 4 and 5).

By replacing the cement with ash, the setting times of the mortars increases. The difference between the initial setting time of the composition without ash and the composition in which 5 wt% of cement was replaced by ash is only 5 minutes. The differences are bigger for higher ash content; it reaches 80 minutes for composition 5 in which 30 wt% of cement was replaced by ash.

The differences are more evident in the case of the final time of setting, where replacement of 5 wt% cement lead to a 30 minutes longer final setting time and replacement of 30 wt% cement with ash a 310 minutes longer time, which means an increase of 1,5 times.

In the case of mortars workability no differences were observed between the composition with no ash and the composition in which 5 wt% of cement were replaced, after that every 10wt% of cement replaced by ash brings 5 minutes in plus.

The density increases slowly by replacing 5% of cement, after that a decrease is observed, every sample densities being under the density of the standard composition. The water absorption is in agreement with the results obtained for the densities. The water absorption decrease from 8,96 % for the standard composition to 8,34 % for composition 2 with 5 wt% ash.

For the other compositions the value of absorption increases to 12,87 %, while the ash proportion was increased to 30 wt%.

The values for the mechanical strength state the observations at the density and absorption determination. Thus an increase in strength, both flexural and compressive, was observed for the composition 2 with 5 wt% ash. While the ash content was increased the mechanical strength decreased and it is situated below the standard composition strength.

The mechanical test after 56 day of hardening shows that the strength increase is higher for the compositions with ash. In the figure 9 are presented the proportions of the strength increase from 28 to 56 days.

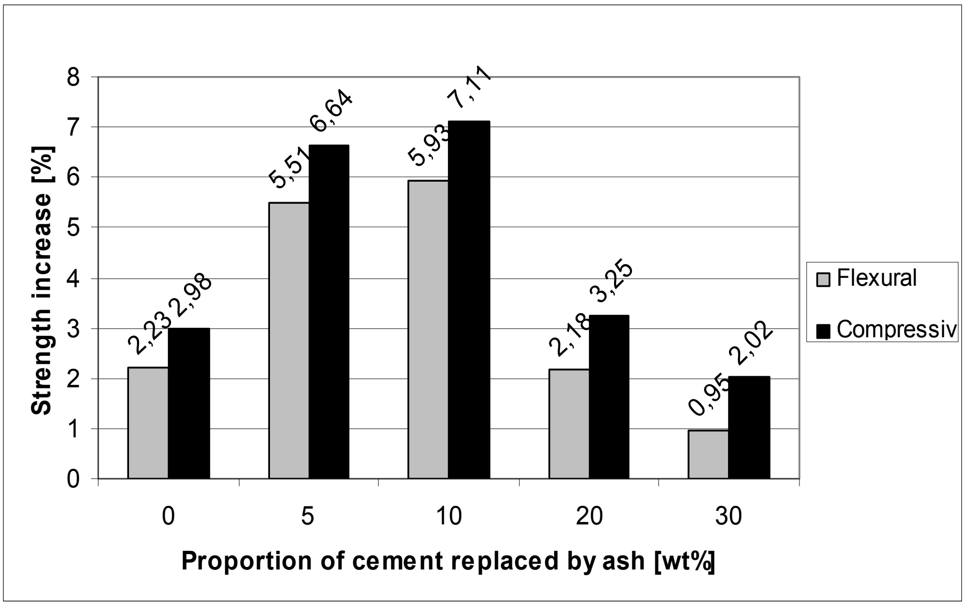

Figure 9. The increasing strength from 28 to 56 days in function of proportion of cement replaced by ash.

CONCLUSIONS

It can be concluded that the Zalău power plant ash can be used in mortar compositions. Replacement of 5 wt% cement by ash brings both economical and qualitative benefits.

Using power plants ash presents some advantages: ash is a cheap unconventional raw material, which introduce in mortar composition determine the decrease of production cost with 10-20%, without any quality compromises; the mechanical strength and durability of the product can be improved.

EXPERIMENTAL SECTION

In this experimental works 5 compositions of masonry mortars were prepared replacing the cement with different amounts of ash. The fresh and hardened mortars characteristics were investigated. The compositions were prepared by forced mixing using a laboratory mixer. The fresh mortar was cast in metallic moulds obtaining 160x40x40 mm prisms which were subjected to testing in hardened state.

In the table 1 are presented the proportions of the raw materials used in the compositions. The first composition, without ash is the standard composition.

Table 1. Mortar compositions

	1	**2**	**3**	**4**	**5**
CEM II/A-S 32,5 R %	25	23,75	22,5	20	17,5
Ash %	0	1,25	2,5	5	7,5
Sand 0-4 %	75	75	75	75	75
+ Water %	17,70	17,90	18,10	19,40	20,80

Three types of raw materials were used for the experimentation.

a) Cement - CEM II/A-S 32,5 R

►Chemical and physical–mechanical characteristics:

Initial setting time Min 75 min.
Soundness Max 10 mm.
Compression strength:
After 2 days: Min 10 N/mm^2
After 28 days: Min 32.5 N/mm^2
Max 52.5 N/mm^2
Sulphate content (SO_3) Max 3.5%
Chloride content Maxim 0.10%

b) The chemical composition and the grain size distribution **of the power plant ash from Zalău** are given in Table 2 and 3.

Table 2. Chemical composition of the ash.

Oxides [wt %]								
SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	L.O.I.
59,71	21,62	0,62	7,10	4,48	1,02	0,60	2,60	1,31

Table 3. Grain size distribution.

Fraction	Percent [wt %]
> 2mm	6,33
> 1mm	5,58
> 500µm	12,00
> 200µm	42,52
> 100µm	25,29
< 100µm	8,28

c) SAND 0-4 mm in conformity with SR EN 13139:2003 (Aggregates for mortar)

Table 4. Determination of particle size distribution of the sand – Sieving method SR EN 933-1/2002.

Sieve [mm]	Rest on sieve (R_i) kg	Refuse percent (Ri//M1) 100 [wt %]	Cumulated percents of refuse 100-(Ri//M1 100) [wt %]
8	0	0	100
4	0	0	100
2	0.019	9.5	90.5
1	0.0384	19.2	71.3
0.25	0.1144	57.2	14.1
0.1	0.023	11.5	2.6
0.063	0.0044	2.2	0.4
<0.063	0.0008	0.4	0

Table 5. Sand characteristics.

No	Characteristics	M.U.	Obtained value	Determination methods
1	Fine particle content	%	0,40	SR EN 933-1:2002
2	Sand equivalent (SE_4)	%	74	SR EN 933-8:2001
3	Impurities content - -humus	-	Light yellow	SR EN 1744-1:2004
5	Loose bulk density	Mg/m^3	1,50	SR EN 1097-3:2002
6	Voids	%	44,3	SR EN 1097-3:2002
7	Absolute density	Mg/m^3	2,71	SR EN 1097-6:2000
8	Oven dried real density	Mg/m^3	2,57	SR EN 1097-6:2000
9	Saturated dried surface real density	Mg/m^3	2,62	SR EN 1097-6:2000
10	Water absorption in 24 h	%	1,98	SR EN 1097-6:2000
11	Composition, content - chlorides - carbonates - total sulphur - sulphates	%	 - 1,26 0,56 0,42	SR EN 1744-1:2004

REFERENCES

1. Gao Pei-wei, Lu Xiao-lin, Lin Hui, Li Xiaoyan, Hou Jie, *Fuel*, **2007,** *86*, 1208.
2. Sarat Kumar Das Yudhbir, *Cement and Concrete Research*, **2006**, *36*, 1827.
3. N. P. Rajamane, J. Annie Peter, P.S. Ambily, *Cement & Concrete Composites*, **2007,** *29*, 218.
4. Tsong Yen, Tsao-Hua Hsu, Yu-Wen Liu, Shin-Ho Chen, *Construction and Building Materials*, **2007,** *21*, 458.
5. Takeshi Yamamoto, Tsutomu Kanazu, Masateru Nambu, Takao Tanosaki, *Fuel*, **2006**, *85*, 2345.
6. Serdar Aydın, Halit Yazıcı, Hüseyin Yigiter, Bülent Baradan, *Building and Environment*, **2007,** *42,* 717.