COMPARISON BETWEEN THE PROPERTIES OF BUILDING MATERIALS MANUFACTURED FROM BOTTOM ASH AND FLY ASH PART II. RESULTS AND DISCUSSIONS

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Abstract. Bottom ash resulting from combustion of low-quality lignite in Romanian coal-fired power plants contains significant amounts of unburned carbon. This large value is caused by many factors, such as the high humidity value of the raw coal delivered to the plant, advanced wear of the coal mills and large variability of the coal quality. As the unburned carbon reduces significantly the economic efficiency of the power generation, solutions to improve the process were investigated.

Within the CHARPHITE project we propose a recycling process of coal ash for obtaining a carbon concentrate that can be used as raw material for graphitization procedure. Various secondary waste materials result from separation and concentration phases of the recycling process.

We point out the possibilities to use the by-products with very low carbon content as substitutes for natural aggregates in ceramic bonded construction materials. We tested two kind of coal ash: bottom ash collected from a Romanian power plant and fly ash collected from a Portuguese power plant.

In the second part of the paper, we present the main characteristics of the building materials manufactured from coal-ash and clay mixtures.

Keywords: coal combustion products, building materials

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1. TEST METODS

The test samples were manufactured according to the procedure presented in the first part of the work, being cylinders with a diameter of 50 mm and a height of 50 mm – fig. 1. We chose to apply the pressure of 51 Mpa, in two stages, with aeration at 5 Mpa, for a better compaction of the mixture. Higher pressures lead to the generation of mechanical stresses that can damage the samples during or after burning [1].

The samples were dried at room temperature for 24 h and then in a thermostatic electric oven at 110 ^{o}C to evacuate the moisture – fig. 2.

After drying, the samples were fired in an electrical furnace by applying a growing gradient of temperature of 3 ^{o}C/min, the maximum temperature being maintained for 3 hours. The heating program and the maximum temperature maintaining time were chosen so that the carbon contained in ash and the organic matter contained in clay would burn completely – fig.3.

Fig. 1. Raw samples

Fig. 2. Dried samples

Fig. 3 Fired samples

The samples made from bottom ash and clay were burned at three different temperatures (970, 1000 and 1030 ^{o}C) in order to compare the main characteristics according to the temperature.

In the literature, it is shown that the use of fly ash for bricks leads to the increase of compressive strength, especially at temperatures of 1000 ^{o}C [2. 3]. For lower combustion temperatures, the increase in fly ash content leads to decreased compressive strength [3]. Thus, we opted for burning samples made from fly ash only at a temperature of 1000 ^{o}C.

The main characteristics of all ceramic bonded products were determined, namely: compressive strength, apparent density and open porosity.

The method of porosity determination consists of weighing the dried sample, saturating it with liquid (by boiling in water), followed by weighing the sample saturated with liquid, in air and in liquid. The samples were immersed in water, boiled for 5 hours, and then cooled down at room temperature in 16-19 hours. Three samples for each type were tested.

The density of the samples was determined by measuring the weight of each sample and its dimensions. All samples were measured.

We used a compressive test machine to measure the compressive strength – fig. 4. Eight samples for each type were tested.

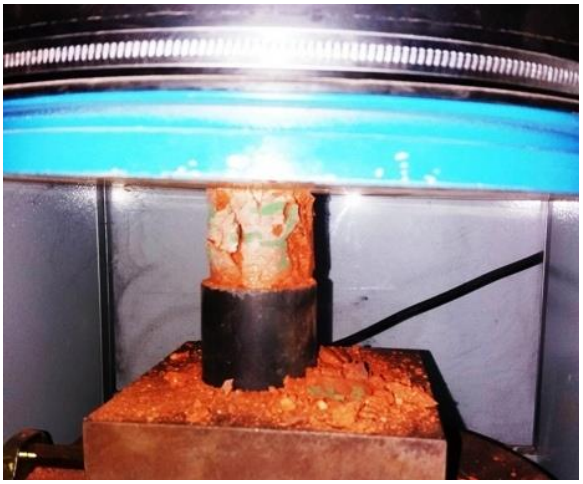


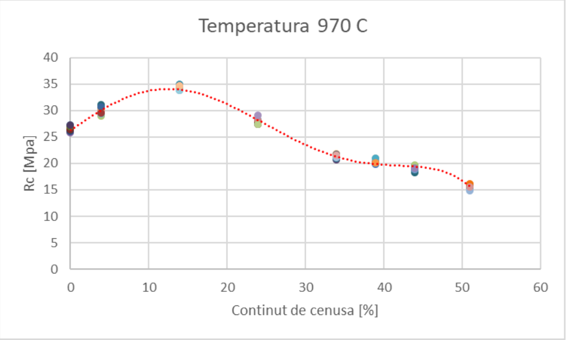
Fig.4. Compressive test machine

2. RESULTS

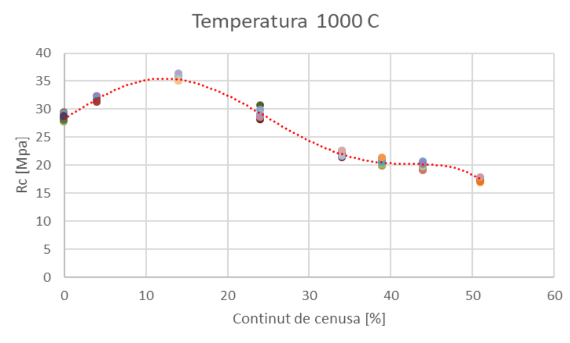
The main characteristics of bottom-ash and clay samples are pointed out in table 1 and in figures 5 .. 7.

Table 1. Main characteristics of bottom-ash and clay samples

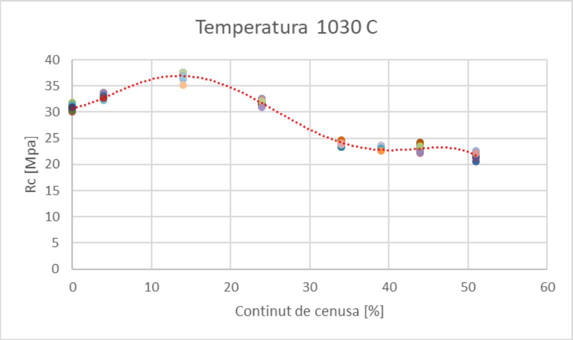
Clay content [%]	Bottom Ash content [%]	Rc [MPa]	Density [kg/m^3]	Open porozity [%]
Firing temperature 970 °C				
100	0	26.41	1.798	29.22
96	4	29.90	1.801	29.62
86	14	34.27	1.757	30.64
76	24	27.88	1.668	32.84
66	34	21.25	1.671	36.88
61	39	20.29	1.656	38.05
56	44	19.10	1.561	38.91
49	51	15.67	1.486	41.25
Firing temperature 1000 °C				
100	0	28.42	1.859	27.23
96	4	31.64	1.858	27.96
86	14	35.49	1.788	29.80
76	24	29.05	1.712	32.01
66	34	21.98	1.694	35.42
61	39	20.71	1.665	36.75
56	44	19.97	1.603	37.76
49	51	17.44	1.474	39.15
Firing temperature 1030 °C				
100	0	30.74	1.938	24.60
96	4	32.88	1.909	25.54
86	14	36.77	1.831	29.07
76	24	31.91	1.766	30.38
66	34	23.87	1.733	33.51
61	39	22.98	1.699	34.58
56	44	23.01	1.610	35.37
49	51	21.71	1.506	36.35



a. Test temperature: 970°C

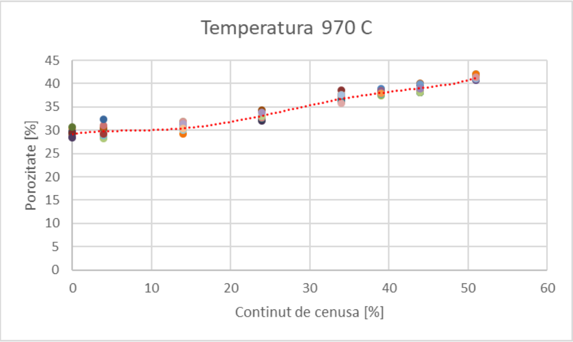


b. Test temperature: 1000°C

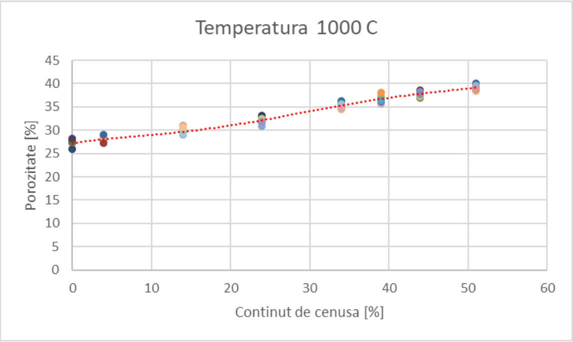


c. Test temperature: 1030^{o}C

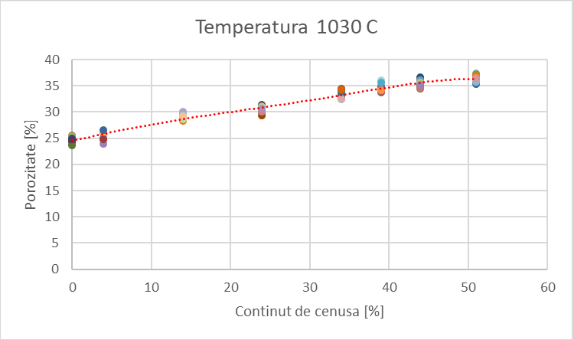
Fig. 5. Compression strength vs. bottom ash content



a. Test temperature: 970^{o}C

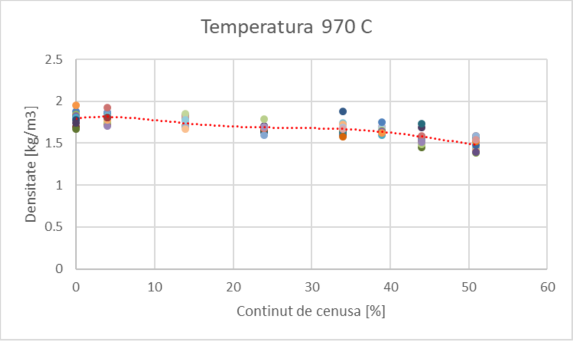


b. Test temperature: 1000^{o}C

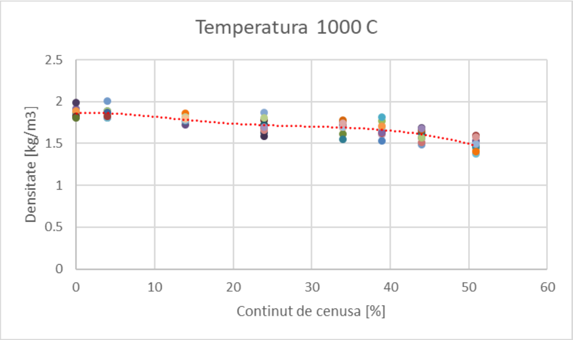


c. Test temperature: 1030^{o}C

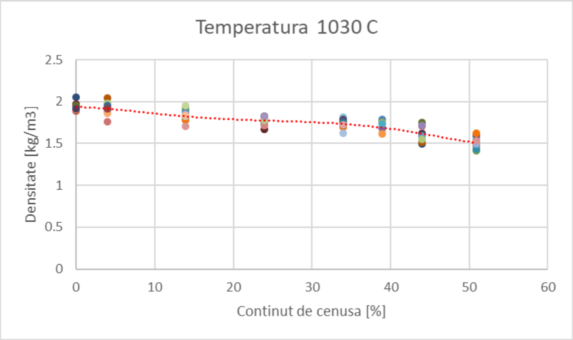
Fig. 6. Open porosity vs. bottom ash content



a. Test temperature: 970^{o}C



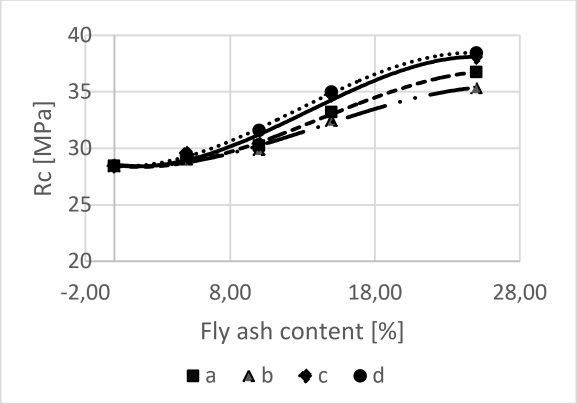
b. Test temperature: 1000^{o}C



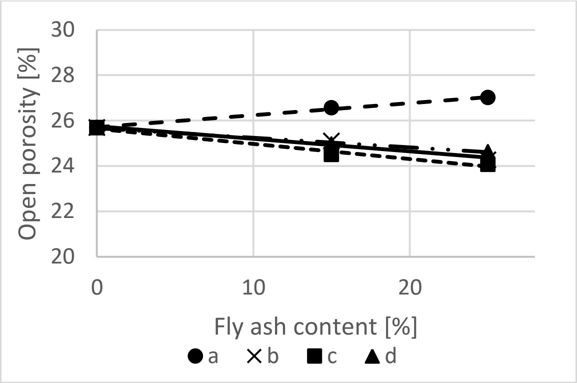
c. Test temperature: 1030^{o}C

Fig. 7. Aparent density vs. bottom ash content

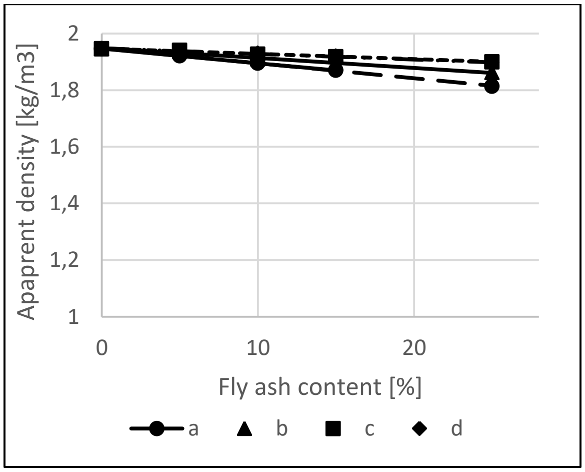
The main characteristics of fly-ash and clay samples are pointed out in figure 8.



a. Compression strength vs. bottom ash content



b. Open porosity vs. bottom ash content



d. Apparent density vs. bottom ash content

Fig.8. Main characteristics of fly ash and clay samples

3. DISCUSSION

From table 2, it can be observed that the firing temperature influences the main characteristics of the ceramic bonded samples. The value of the compression strngth (in MPa) increases with the increase of the firing temperature but, in comparison with the standard sample, the percentage increase is smaller. The compression strngth reaches a maximum for about 15% bottom ash content and then decreases with the increase of bottom ash content.

With the increase of bottom ash content, the apparent density of ceramic bonded products decreases and the open porosity increases compared to the standard series (made exclusively of clay).

The combustion of the unburned coal from bottom ash naturally causes the increase of the open porosity, respectively the increase of the thermal and sound insulation capacity of the final product. The organic components of the products were totally removed in the combustion stage at 1030 ^oC.

Table 2. Percentage variance of the main parameters

Bottom ash content	Firing Temp [%]	Percentage variance [%]		
		Compr. Strength	Apparent Density	Open porosity
14%	970	29.73	-2.29	4.88
	1000	24.86	-3.86	9.45
	1030	19.62	-5.52	18.19
24%	970	5.56	-7.26	12.39
	1000	2.19	-7.95	17.57
	1030	3.83	-8.91	23.50
51%	970	-40.68	-17.38	41.19
	1000	-38.65	-20.75	43.79
	1030	-29.38	-22.31	47.78

Taking into account the high melting temperature of ash (over 1200 ^oC), the technological process can be applied to manufacture heat-insulating refractory bricks with a maximum use temperature of 1000 - 1050 ^oC, replacing the classic variants of technologies with combustible additives, which commonly use wood sawdust as a component in the formation mixtures.

The apparent density and the open porosity of the ceramic bound samples vary much less when using fly ash (see table 3) because it has a very low carbon content and is homogeneous, having dimensions smaller than 0.075 mm.

Table 3. Percentage variance of the main parameters

Fly ash type	a	B	c	d
	Fly ash content 15%			
Compr. Strength	16.71	14.18	22.06	23.04
Open porosity	3.38	-2.29	-4.59	-2.78
Apparent density	-3.90	-2.67	-1.43	-1.33
	Fly ash content 25%			
Compr. strength	29.23	24.34	33.88	35.22
Open porosity	5.15	-5.54	-6.32	-4.08
Apparent density	-6.78	-4.31	-2.36	-2.56

The open porosity increses very slow with the ash content for the Type A of fly ash because of the presence of unburned carbon. For the other 3 types of fly ash, the open porosity decreases with the ash content.

The compressive strength increases with the ash content.

References

[1]. Pérez, J. M., and M. Romero. "Microstructure and technological properties of porcelain stoneware tiles moulded at different pressures and thicknesses." *Ceramics nternational* 40.1 (2014): 1365-1377.

[2]. Leiva, C., et al. "Fired bricks with replacing clay by combustion fly ash in high volume ratio." Proceedings of the GPE – 4th International Congress on Green Process Engineering, Sevilla, Spain, 2014.

[3]. Leiva, C., et al. "Characteristics of fired bricks with co-combustion fly ashes." *Journal of Building Engineering* 5 (2016): 114-118.

[4]. Cucu, Mihai Gabriel, et al. "Polymorphisms in autophagy genes and active pulmonary tuberculosis susceptibility in Romania." *Revista Romana de Medicina de Laborator* 25.1 (2017): 47-53.

[5]. Cristinel Racoceanu, Study on the reduction of polluting emissions through combustion biomass in the thermal boilers, Annals of the „Constantin Brâncuşi", University of Târgu-Jiu,

Engineering Series, no.4 /2018, pag 17-20, ISSN1842-4856.

[6]. Valentim, Bruno, et al. "Undifferentiated inorganics in coal fly ash and bottom ash: Calcispheres, magnesiacalcispheres, and magnesiaspheres." *Minerals* 8.4 (2018): 140.

[7]. Badenhorst, C., Wagner, NJ., 2017. Char extracted from coal ash as a replacement for natural graphite – Charphite. FFF Conference on Sustainable Development of South Africa’s Energy Sources, 29-30 Nov 2017, Johannesburg,

[8]. Cruceru, M., et al. "Possible uses of fossil fuel combustion waste in building materials industry." Proceedings of the 1st International Conference on Health Science and Biomedical System,, ISSN. 2012.

[9]. Predeanu, Georgeta, et al. "Coal ash characteristics to assess its possible uses." International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology & mining Ecology Management (2013): 309.