

The influence of clay fineness upon sludge recycling in a ceramic matrix

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Abstract. The feasibility of sludge recycling in the ceramic manufacture was evaluated through laboratory testing. Such residues have similar chemical and mineralogical composition with the raw mixture of the green ceramic body used in construction. Several ceramic masses with clay and various proportion of sludge have been synthesized and then characterized by their physical-mechanical properties. The fineness of the clay, the main component of the green ceramic body, has been considered for every raw mixture. The proportion of the sludge waste addition depends on the clay fineness and the sintering capacity also, increases with the clay fineness. The ceramic properties, particularly, the open porosity, and mechanical properties, in presence of small sludge proportion (7, 20 %) shows small modification. The introduction of such waste into building ceramic matrix (bricks, tiles, and plates) has a very good perspective.

1. Introduction

Nowadays society is not only concerned in finding new sources of raw materials, but also in recycling waste as new materials [1].

According to Directive 2008/98/EC on waste, Member States shall determine waste prevention programs by the end of 2013, which will be integrated into waste management plans or will operate as separate programs.

Among the main types of waste existing in our country which are suitable for using in construction, which volume and characteristics justifying being studied, the research focused on recovery from power plant ash, phosphogypsum, blast furnace slag and to a lesser extent on urban sewage sludge.

A possible use of sewage sludge is to be used in producing construction ceramic. When we speak about gross construction ceramic we refer to ceramic matters in which composition falls the aluminosilicates, alkali, alkaline earth iron respectively fusible, vitrifiable clays and less refractory clays [2,3]. The variety of chemical and mineralogical composition of the raw materials, processing methods and burning conditions provide the products the most varied characteristics.

The reuse of the sludge from the wastewaters of Saint George city is so reduced that practically, it can't be mentioned. The sludge from the Wastewater Plant of Saint George is going through the drying process, by passing the concentrator of humid sludge and biogas production, used as a source of thermal energy. The waste coming from the wastewater treatment process is thickened, fermented and dried, then transported to the landfill. The humidity of the dried sludge is 70-75%.

Partial incorporation of sewage sludge in crude construction ceramic is a way to use them [4,5].



The present work assesses the incorporation of sewage sludge up to 20% into ceramic materials. This reuse of sludge obtained from water treatment plant provides an alternative recycling and disposal solutions. The objective of the study is to characterize the raw materials and the products by physical and chemical methods and to evaluate the effect of incorporated sludge amounts and the influence of fineness of the clay upon sludge recycling.

2. The experimental part

Through specific operations performed, ceramics with a certain composition were obtained, having the granulation and homogenizing which matched the adopted molding process and the texture to be after heat treatment.

In this paper we studied, by sieving, influence of particle size of raw materials: clay of Bodoc and sludge of waste water plant of Saint-George city, on the properties of ceramics.

The principle is simple and consists of passing the clay and sludge through a set of meshes corresponding to a particle size scales stacked from up to down, in decreasing order. We used sieves the following sizes: 0.2, 0.09 and 0.063 mm.

The following aspects were tracked:

- Specific methods of obtaining different compositions
- Characterization of ceramics (compactness, resistance to bending)

3. Results and Discussion

The chemical analysis showed the compatibility of the materials on Table 1.

Table 1. The oxide composition of the raw materials

Oxide	Standard		Ceramic mass/Calcinated ceramic mass %									
	0		5		7		10		15		20	
SiO ₂	67.97	70.49	65.27	69.83	64.19	69.54	62.57	69.09	59.87	68.34	57.18	67.55
Al ₂ O ₃	15.41	15.99	14.82	15.85	14.60	15.81	14.23	15.74	13.68	15.61	13.12	15.48
Fe ₂ O ₃	4.88	5.06	4.70	5.03	4.63	5.02	4.53	5.00	4.35	4.96	4.18	4.93
CaO	1.66	1.73	2.24	2.40	2.47	2.67	2.82	3.16	3.40	3.87	3.98	4.69
MgO	1.59	1.64	1.51	1.63	1.52	1.62	1.50	1.60	1.45	1.58	1.27	1.49
K ₂ O	2.43	2.52	2.30	2.47	2.26	2.44	2.18	2.40	2.06	2.35	1.94	2.29
Na ₂ O	1.54	1.62	1.46	1.61	1.50	1.60	1.46	1.57	1.43	1.53	0.61	0.72
Other	0.94	0.95	1.16	1.20	1.16	1.28	1.27	1.44	1.39	1.58	2.42	2.85
LOI*	3.58	-	6.51	-	7.67	-	9.44	-	12.37		15.30	-

*LOI at 1000°C

The introduction of small amounts of sludge, up to 10%, does not lead to significant changes in the oxide composition of the mixtures. Only in the presence of large amounts of sewage sludge (15-20%) a more strongly increase of calcium oxide content and a decrease of silica content and merely a small drop of the content of aluminium oxide and iron oxide can be observed.

However, even in the presence of large amounts of sludge (20%) in clay mixture, its chemical and oxidical composition is within the limits of the composition corresponding to construction ceramic masses: ceramic blocks, bricks, tiles, roofing tiles.

The analysis of granulometric distribution of the clay particles has been done with a MALVERN Mastersizer 2000 laser granulometry analyzer in liquid suspension with a measurement scale between 0.02-600 microns. The granulometric bend of Bodoc clay is shown in Figure 1. The size of the particles ranges between 0.45 to 600 microns. There is a significant amount of small particles of 10-12 µm, in a single-mode distribution. The specific surface area has a value of 0.781 m²/g [7,8].

The analysis of granulometric distribution of the sludge particles has been done on the base of a FRITSCH Analisette 22 laser granulometry analyzer, in liquid suspension 0.1-600 microns.

The granulometric bend of sludge is shown in **Figure 5** and it highlights particle size with values between 1-108 μ m. The line is continuous, and it shows a cumulative shift. The specific surface area has a value of 0.59 m²/g [7,8].

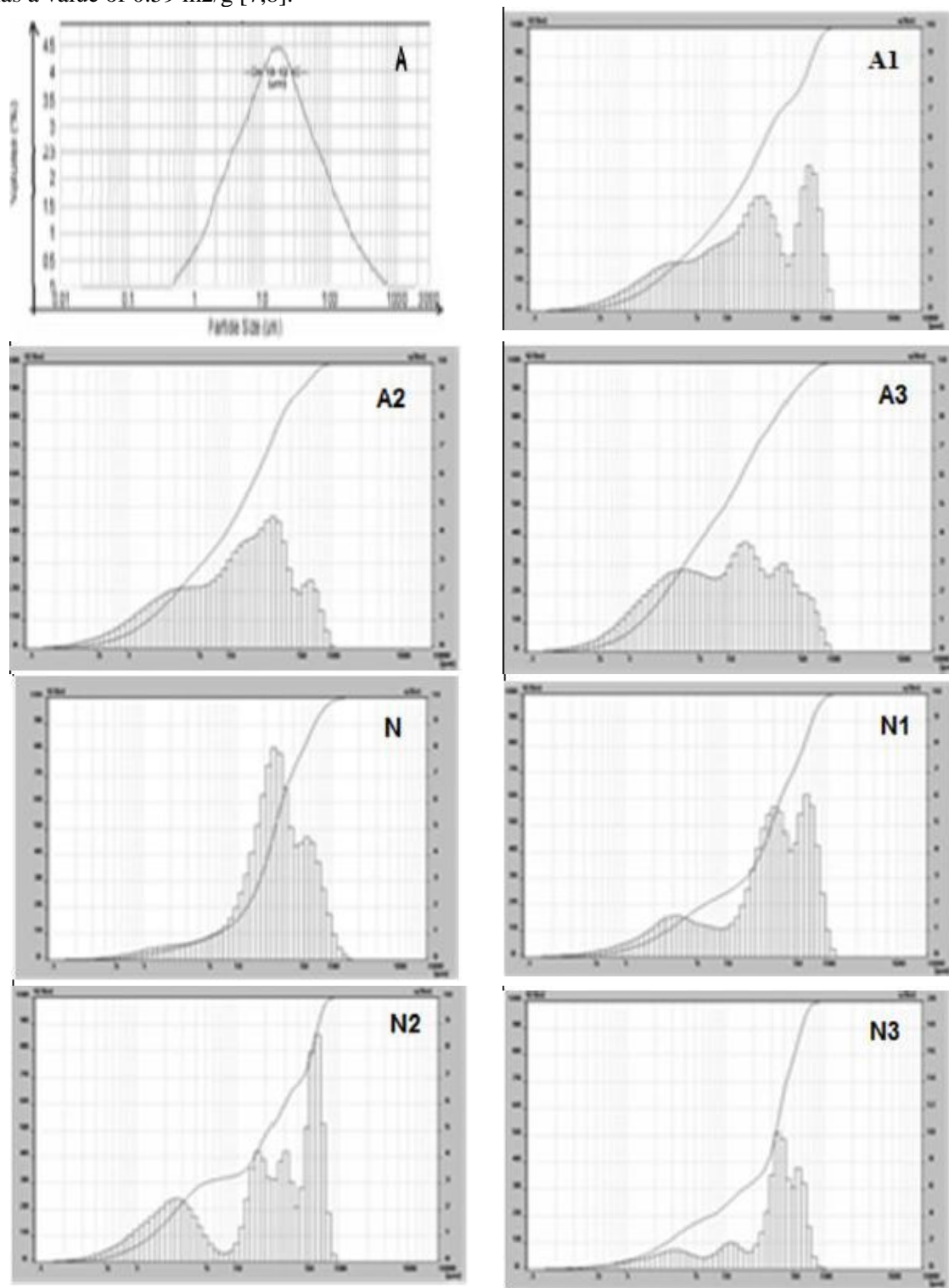


Figure 1-8. Grain size distribution of clay (A) and sewage sludge (N) before and after passing through 0.2 mm (1), 0.09 mm (2) and 0.063 mm (3) sieves

The advanced fineness of sewage sludge ensures a good condition for conducting reactions in solid phase in mixture with clay of Bodoc. On the other hand, in case of small amount of sludge in the clay mass, it is necessary a very good mixing to get a homogeneous mass.

Granulometric analysis was used for the determination of grain size by passing the raw materials through various sizes of mesh sieves, ranging from 0.063 mm to 0.2 mm, as indicated in **Figures 1-8**.

The prepared mixtures are presented in **Table 2**, but we focus more on the addition of 7 and 20 %.

Table 2. Prepared mixtures

Ceramic mass	Clay, %	Sludge, %
reference mass	100	-
1.	95	5
2.	93	7
3.	90	10
4.	85	15
5.	80	20

We determined the compactness characteristics of the ceramic masses, at the same time the resistance to bending of ceramics have been determined and they are presented in **Table 3**. These were burnt at 960 °C temperature.

Table 3. Compactness characteristics at 960°C (**D** – density, **A** – adsorption, **P** – porosity) and variation resistance to bending according to temperature (**R_i**)

Sieve dimension (mm)	Clay				Ceramic mass							
					7 % sewage sludge				20 % sewage sludge			
	D	A	P	R_i	D	A	P	R_i	D	A	P	R_i
0.2	1.90	15.07	29.54	3.55	1.81	17.03	30.74	3.25	1.54	25.19	38.39	3.17
0.09	1.88	15.70	28.76	4.12	1.80	18.11	31.04	4.02	1.61	24.59	38.77	2.71
0.063	1.80	18.20	32.79	10.54	1.79	19.06	33.70	8.40	1.63	23.55	39.66	7.13

As we expected, the increase of the heat treatment temperature positively influences the densification of ceramic masses with or without adding sewage sludge - Table 3. The apparent density slightly increases along with the increase of the burning temperature from 960 °C to 1100 °C, even in the case of sample containing 20% of sludge in the mass.

However, increasing the amount of sludge from 7% to 20% in the ceramic mass, there was an increase in the apparent porosity and consequently an increase in the values of water absorption in all cases.

The mechanical properties of ceramic masses, expressed by mechanical resistance to compression and bending were strictly dependent on the compactness of ceramic masses, so influenced by apparent density. The mechanical resistance was affected, firstly, by the temperature of the heat treatment - when these increased it increased too, and secondly by the amount of added sludge in ceramic mass – this decreased when the amount of sludge increases in ceramic mass. Reduction of mechanical strength is visible to the masses with 20% sludge - the values are given in Table 3.

4. Conclusion

Based on the study, we can conclude that increasing the fineness of particles in ceramic masses has its influence on the following properties:

- The increase of resistance to bending of the ceramic mixture is mainly due to the increase of the fineness of the particles.
- When you increase the fineness of the particles, the porosity values increase slightly.

- It is clear that the sewage sludge samples, used in the experiments, from Saint George (Covasna) are proper for gross construction ceramics (bricks).

The successful incorporation of 20% sludge amount into ceramic masses is a unique result, which cannot be found in the literature.

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