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Study on the possibility to use ashes from coal power stations for production of construction ceramics

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Abstract
The possibility to use ashes from coal power stations as raw material for production of construction ceramic items was studied. Blend compositions with different contents of ashes, clay and coal were worked out. The ceramic materials synthesized were characterized by X-ray phase analysis. The basic physicochemical and mechanical properties of the samples prepared were determined.
The ceramic materials obtained from all of the blends prepared shoed properties conforming to the standard BDS EN ISO 10545 for industrial production of common clay bricks.
Keywords: *Ceramic building materials, coal ash, bricks, properties.*

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I. INTRODUCTION

In recent years, much effort have been devoted to the effective utilization of industrial wastes for production of various materials. On world scale, the coal power stations are one of the biggest generators of such waste.This can lead to significant ecologic problems related to environment contamination, as well as with their deployment.

Ashes from the coal power stations are secondary product from the combustion of mineral coal[1,2]. By its macro component composition, it can be regarded as aluminosilicate material and additional source of minerals. The main components of the ashes are SiO_2, Al_2O_3 and Fe_2O_3 and small quantities of CaO, MgO and other oxides[3]. The chemical composition and the fine grain morphology determine the ashes from the thermal power stations as material suitable for the ceramic industry replacing the traditional natural materials[4]. The studies of research teams are focused on the use of ashes in the glass[5] and glass-ceramic industry[6], for production of ceramic items[7,8], as a structural filling material[9], as an effective filling material in civil engineering applications like underwater fills, light weight back fills and for light weight structural filling applications and various cement composites[10,11].

The aim of the present work is to study the possibility to utilize ashes from thermal power station as raw material for production of construction ceramic items conforming to the requirements of the standards.

II. MATERIALS AND METHODS

The raw materials used for the experiments were ashes from thermal power station, clay from the "Buchvata" bed and brown coal. The chemical compositions of the initial materials are shown in Table 1.

Table 1. Chemical composition of the initial materials, mass%

Oxide content	Ash	Clay	Coal
SiO_2	48,32	63,44	22,00
Al_2O_3	17,90	15,25	10,48
Fe_2O_3	18,01	4,81	3,68
CaO	4,52	5,63	1,88
MgO	2,34	1,46	0,8
$Na_2O + K_2O$	2,40	1,76	-
TiO_2	0,87	-	-
MnO	0,04	-	-
SO_3	-	-	1,16
LOI	5,60	7,65	60,00

The ashes from the power station have amorphous-crystalline structure (Fig.1). Its main components are SiO_2, Al_2O_3, Fe_2O_3 and oxides of alkali-earth metals. The basicity modulus (M_o) of the ashes determined by the ratio between the sum of the basic oxides and the sum of the acidic ones was 0,1. This classifies the ashes used for the experiments as superacidic one.

The clay from the "Buchvata" bed is classified as medium plastic, easy melting and medium binding ability. It contains mainly SiO_2(63,44%) and Al_2O_3(15,25%).

The coal used for the experiments was a clay-combustible mixture of brown coal and clay of class 0-40 mm. Their caloricity is 2700 – 3700 Kcal/kg and ash content 40%.

Fig.1 shows the crystalline phases of the initial materials determined by X-Ray Diffraction (XRD). The results obtained from the analysis indicated that the power station ashes are heterogeneous material containing both crystalline and amorphous phases. The crystalline phases were quartz, magnetite and albite.

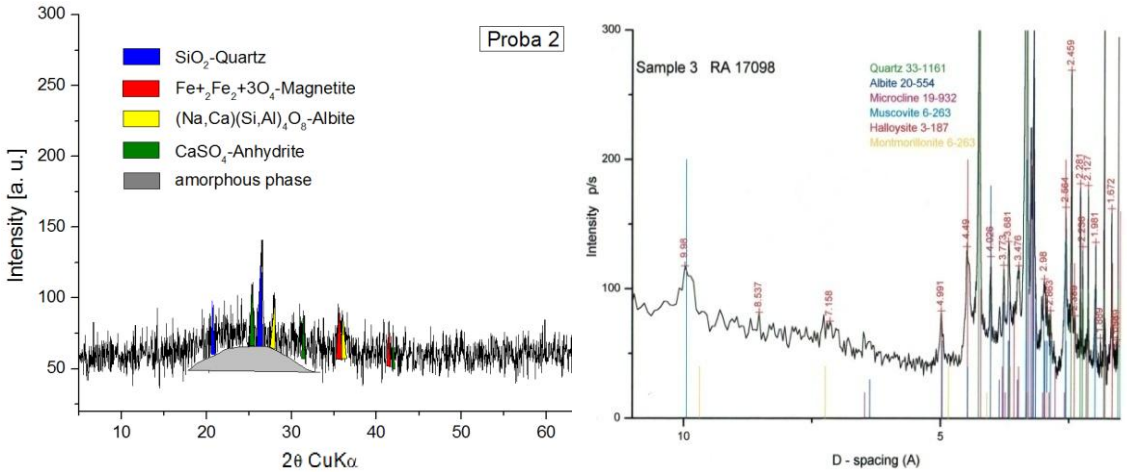

Fig.1. Diffractograms of raw materials: a)Ash; b)Clay

The mineralogical composition of the clay was as follows: quartz (30%), muscovite (18%), halloysite (14%), albite (14%), montmorillonite (12%) and microcline (10%).

For the experiments, blends were prepared from clay and ashes (compositions $M_1 – M_3$) and from clay, ashes and coal at constant coal content (compositions $MC_1 – MC_4$). Detailed compositins of the blends prepared are presented in Table 2.

Table 2. Compositions of the blends, mass%

Composition	Ash	Clay	Coal
M	100	-	-
M1	90	10	-
M2	80	20	-
M3	70	30	-
MC1	60	20	20
MC2	50	30	20
MC3	40	40	20
MC4	30	50	20

Based on the compositions of the blends, the chemical compositions of the blends were calculated and they are shown in Table 3.

Table 3. Chemical compositions of ceramics blends, mass%

Composition	M	M_1	M_2	M_3	MC_1	MC_2	MC_3	MC_4
SiO_2	48,32	49,83	51,35	54,37	46,08	47,59	49,10	50,62
Al_2O_3	17,90	17,64	17,37	16,84	15,89	15,62	15,35	15,09
Fe_2O_3	18,01	16,69	15,37	12,73	12,51	11,19	9,87	8,54
CaO	4,52	4,63	4,74	4,97	4,21	4,32	4,44	4,55
MgO	2,34	2,25	2,16	1,99	1,86	1,77	1,68	1,59
$Na_2O + K_2O$	2,40	2,34	2,27	2,14	1,79	1,73	1,66	1,60
TiO_2	0,87	0,78	0,70	0,52	0,52	0,44	0,35	0,26
MnO	0,04	0,03	0,03	0,02	0,02	0,02	0,02	0,01
SO_3	-	-	-	-	0,23	0,23	0,23	0,23
LOI	5,60	5,81	6,01	6,42	16,89	17,09	17,30	17,51

The sample blends were mixed and homogenized by combined milling in a ball mill for 3h, plasticized with 8% distilled water. After granulation trough a 0,5mm sieve, samples were prepared from the blends by the method of semidry pressing under pressure of 50MPa.

The samples were sintered in superkanthal furnace „Naber“ equiped with programming regulator „EVROTERM“ 822 to control the sintering process. The sintering was carried out at temperatures in the interval 900 - 1150°Cat heating rate – 5°C/min and isothermal period at the highest temperature 3 h.

III. RESULT AND DISCUSSION

Fig. 2 shows a photograph of the ceramic samples synthesized. Depending on their chemical composition and sintering temperatures, the samples are different by color and structure. No visible defects or swelling was observed. The samples obtained from composition M (denoted by circle) had red-brown color and the best sintering compared to the other blends.

Fig. 2. Photograph of ceramic samples

The ceramic samples prepared were characterized with respect to water uptake, apparent density and apparent porosity. The results obtained are presented in Tables 4 and 5.

Table 4. Physicochemical properties of samples M – M_3

Parameter	Blends	900ºC	950ºC	1000ºC	1150ºC
Apparent density $\rho_{app}.10^{-3}$, kg/m^3	M	1,58	1,60	1,62	1,64
	M_1	1,61	1,63	1,65	1,67
	M_2	1,63	1,64	1,66	1,73
	M_3	1,67	1,70	1,75	1,80

Water absorbtion, %	M	28,70	27,40	25,90	24,40
	M_1	27,45	25,56	24,24	22,81
	M_2	25,63	25,12	24,41	21,77
	M_3	23,13	22,36	21,22	19,64
Apparent porosity, %	M	45,35	43,84	41,96	40,02
	M_1	44,20	41,66	40,00	38,81
	M_2	41,77	41,20	40,52	37,67
	M_3	38,62	38,02	37,13	35,36

It can be seen from the data shown in Table 4 that the apparent density, water uptake and apparent porosity depend on the contents of ashes and sintering temperature.The apparent density increased from 1.58 to 1.80 kg/m^3 with the increase of the sintering temperature and clay content. Accordingly, the water uptake and apparent porosity decreased.

Diffractograms of samples prepared from blends M1 and M3 at sintering temperature of 1050ºC are presented in Fig.3.

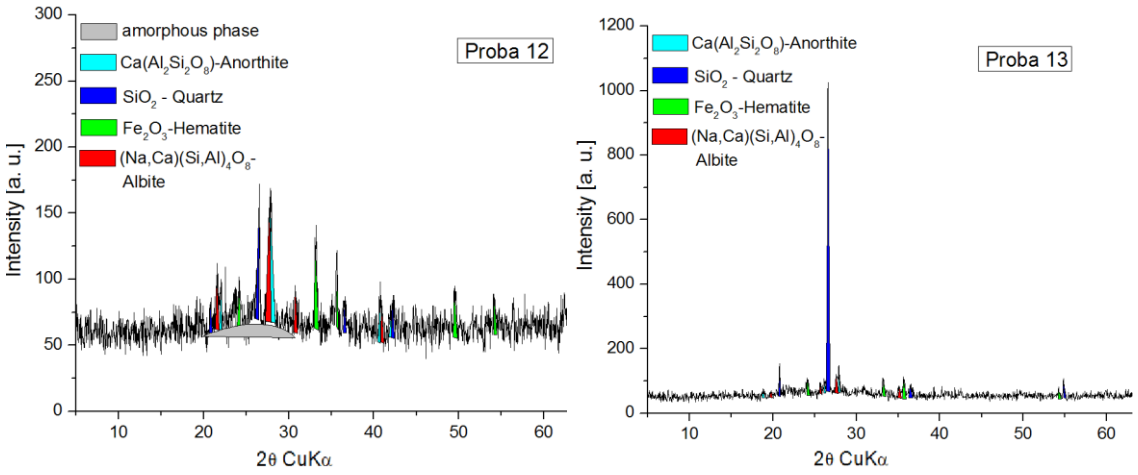

Fig.3. Diffractograms of blends: a)M_1; b)M_3

The content of amorphous phase was found to decrease with the decrease of the contents of ashes (blend M_1). The content of anortite increased at the expense of the decrease of albite content (blend M_1 compared to pure ash). No amorphous phase was registered for blend M_3.

Blends MC_1 – MC_4 had constant coal content of 20 mass%. The ash content decreased from 60 to 30 mass% while the clay content increased from 20 to 50 mass%. The results obtained from the sintering of these blends are presented in Table 5.

For blends MC_1 – MC_4 (Table 5), the tendency observed was increase of the apparent density with the increase of the sintering temperature, while the apparent density decreased with the decrease of ash content. A tendency of increase of water uptake up to 39% at sintering temperature of 900ºC and the apparent porosity up to 56% was observed for blend MC_4.

Table 5. Physicochemical properties of samples MC_1 – MC_4

Parameter	Blends	900ºC	950ºC	1000ºC	1150ºC
Apparent density $\rho_{app}.10^{-3}$,kg/m^3	MC_1	1,53	1,52	1,54	1,56
	MC_2	1,48	1,50	1,52	1,54
	MC_3	1,46	1,48	1,50	1,52
	MC_4	1,44	1,46	1,48	1,50
Water absorbtion, %	MC_1	34,80	33,10	31,70	30,11
	MC_2	36,30	34,44	33,21	31,52
	MC_3	37,81	36,10	34,60	34,10
	MC_4	39,21	37,41	36,11	34,41
Apparent porosity, %	MC_1	52,20	50,31	48,82	46,97
	MC_2	53,72	51,60	50,48	48,54

	MC_3	55,20	53,43	51,90	50,31
	MC_4	56,46	54,62	53,44	51,62

These results were explained with the fact that coal also took part in the combustion so greater amount of gaseous phase was released during the sintering which affects the porosity and density of the samples despite that the content of alkali oxides increased almost twice.The losses by the sintering of blends MC were four times higher compared to blends M.The samples sintered from blends M appeared much lighter by color and visually more porous.

Fig.4 shows the diffractograms of samples prepared form blends MC_2andMC_4. For both blends, the characteristic reflexes for anortite, quartz, hematite and amorphous phases were registered.

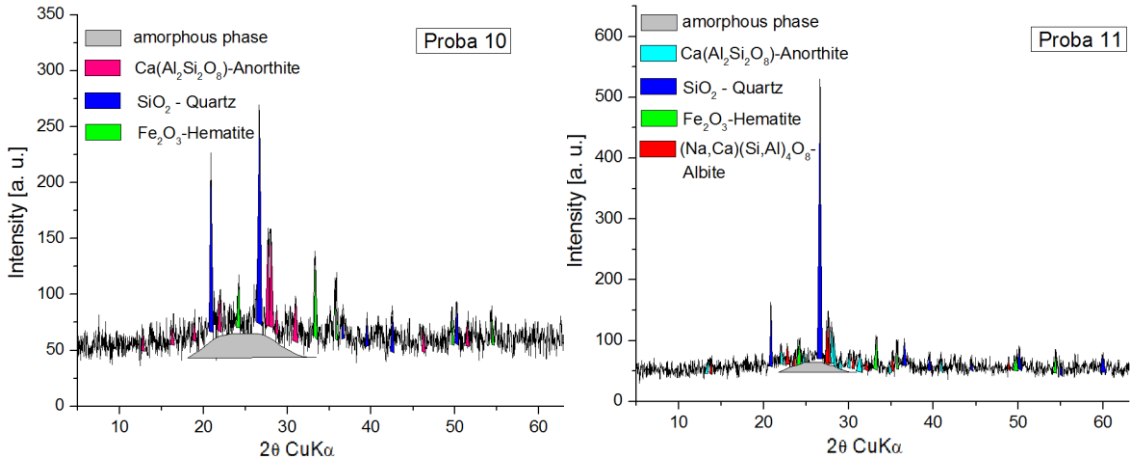

Fig.4. Diffractograms of blends: a)MC_2; b)MC_4

For blend MC_4, the content of amorphous phase sharply decreased with the decrease of the ash content. New crystalline phase was observed – albite while the contents of anortite and hematite decreased.

The mechanical strength is an important property for the construction ceramic wares. Fig.5 shows the results obtained for compression strength and bending strength of the samples studied.

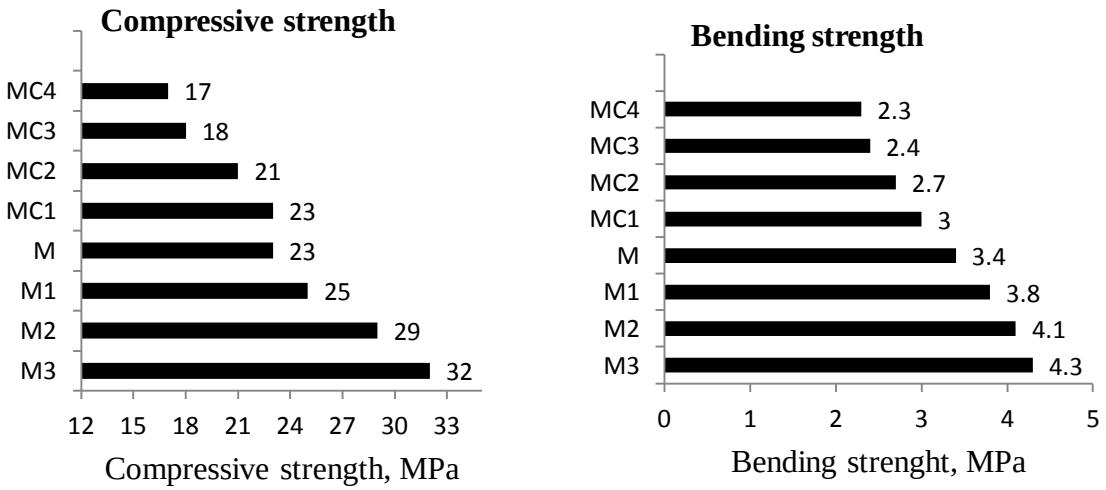

Fig.5. Mechanical strength of samples at 1050°C

It was found that the increase of the ash percentage in blends MC_4 – MC_1 improved the mechanical properties of the samples. The values obtained correlated well with the values of the apparent density. The samples prepared from MC blends had compression strength in the range of 17-23MPa. The compression strength for blends M_3-M_1 increased from 23 to 32MPa. The highest bending strength observed was 4,1MPa for the sample prepared from blend M_1.

IV. CONCLUSION

According to BDS EN ISO 10545 „common clay bricks“, the common purpose bricks should conform to the following requirements:

- Water uptake (%)- not less than 10;
- Compression strength (MPa) –not less than 6;
- Bending strength (MPa) –not less trhan1,4.

Comparing the results obtained to the BDS, it can be seen that the samples sintered from all the blends prepared conform to the requirements of BDS EN ISO 10545 with respect to water uptake and mechanical strength.

REFERENCES

[1]. GollakotaA., VolliV., Shu Chi-Min (2019) “Progressive utilisation prospects of coal fly ash: A review” Sci. Total Environ Vol. 672, Pp. 951-989.
[2]. Panda L., Dash S. (2020) “Characterization and utilization of coal fly ash: a review”Emerg. Mater. Res. Vol.9, №3, Pp. 921-934.
[3]. SinghS., RamC., MastroR., Verma S.(2011)“A comparative evaluation of minerals and trace elements in the ashes from lignite, coal refuse, and biomass fired power plants”, Int. J. Coal Geol., Vol. 87, №2, 112-120.
[4]. AhmaruzzamanM. (2010) “A review on the utilization of fly ash”Prog. Energ. Combust., Vol.36, Pp. 327-363.
[5]. Sheng J., Huang B.X., Zhang J., Zhang H., Sheng J., Yu S., Zhang M., (2003) “Production of glass from coal fly ash”, Fuel, Vol.82, №181, Pp. 181-185.
[6]. Zhu M., Ji R., Li Z., Wang H., Liu L., Zhang Z. (2016) “Preparation of glass ceramic foams for thermal insulation applications from coal fly ash and waste glass”Constr. Build. Mater. Vol. 112, Pp. 398-405.
[7]. LuoY., Zheng S., Ma S., Liu C., Wang X. (2017) “Ceramic tiles derived from coal fly ash: Preparation and mechanical characterization” Ceram. Int. Vol. 43, № 15, Pp. 11953-11966.
[8]. Ji R., Zhang Z., Yan C., Zhu M., Li Z.(2016) “Preparation of novel ceramic tiles with high Al2O3 content derived from coal fly ash” Constr. Build. Mater., Vol.114, Pp. 888-895.
[9]. DewanganP., PradhanM., KishoreN.(2010) “Utilisation of fly ash as a structural fill material for safe and sustainable development: Need of the hour”, Indian Min. Eng. J. Mine Tech. Pp. 134-139.
[10]. Sow M., Hot J., Tribout C., Cyr M. (2021) “Improving circular economy by the valorization of non-conventional coal fly ashes in composite cement manufacturing”Constr. Build. Mater., Vol.300, Pp. 124053.
[11]. Demi D., Marku J. (2011) “The use of fly ash in cement produced in fushekruja cement factory” J. Environ. Prot. Ecol.Vol.12,№2, Pp. 587-593.