EFFECT OF WHEAT STRAW AND SUNFLOWER SEEDS HUSKS AS PORE FORMING AGENTS ON THE PROPERTIES OF POROUS CLAY BRICKS

Angel Georgiev, Albena Yoleva, Stoyan Djambazov

University of Chemical Technology and Metallurgy
8 Kl. Ohridski, 1756 Sofia, Bulgaria
E-mail: djam@uctm.edu

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ABSTRACT

The interest towards introduction of agricultural biomass wastes to porous clay bricks is increasing lately. These pore-forming agents start to ignite during the firing process providing extra thermal energy inside the product and decreasing the required external energy required. Besides this effect, their combustion increases the porosity of the final product resulting in enhanced thermal insulation properties. This paper presents the effect of adding biomasses (wheat straw and husks of sunflower seeds) in quantity of 3,5 mass % and 8 mass % on the physical and thermal properties of clay porous bricks fired at 900°C. The results show increase of the apparent porosity compared to fired clay and decrease of the thermal conductivity of the products. There is a significant positive correlation between the increasing quantity of organic matter and the porosity. This study shows that 5 mass % of wheat straw and 3 mass % of sunflower seeds husks can be used as pore forming agents in bricks production to improve their thermal conductivity and keep acceptable compressive strength.

Keywords: biomass, porous clay bricks, porosity, thermal conductivity.

INTRODUCTION

Porous ceramic bricks of low thermal conductivity are one of the important materials used in construction industry. Clay based bricks are the most widely used building materials for many purposes such as load carrier walls, decorative and isolation walls, etc. Thermal conductivity reduction can be achieved by addition of pore forming additives to the ceramic bodies. The increasing demand of low cost and lightweight ceramic materials in building industry has brought about the need of studying new raw and additive materials which can provide increase of the ceramic bricks porosity [1 - 5].

Numerous pore-forming agents have been tested in the literature. These additives can be divided into two groups: those from renewable resources (rice husks, rice straw, husks of sunflower seeds, wheat straw, waste tea, coffee waste, sawdust, cigarette butt, olive stone flour, sugarcane bagasse) and those from mineral resources (slag, marble, glass, zeolite, fly ash, perlite, diatomite, calcite, pumice, vermiculite) [6 - 16]. Organic type pore-forming additives are most frequently used and are a possible solution in respect to heat demand and porosity creation. These additives, used mainly to produce lightweight materials, modify also other properties like porosity, water absorption, density, mechanical resistance and thermal insulation. It is crucial for these porous materials to find a compromise in order to produce an innovative product with both high mechanical and thermal performance [3 - 8].

The aim of this paper is to evaluate the physical and mechanical properties of porous ceramic materials manufactured by adding wheat straw (WS) and husks of sunflower seeds (HSS) residues in quantities of 3, 5 mass % and 8 mass % to the clay body.

EXPERIMENTAL

The present experimental study was performed using WS and HSS (3, 5 mass % and 8 mass %) in the clay body. All clay bodies contained 1,2 mass % coal dust. A composition

Table 1. Clay bodies composition (mass %).

Composition / Raw materials, mass %	0	1	2	3	4	5	6
Clay Lucovite	100	100	100	100	100	100	100
Wheat Straw		3	5	8			
Husks of sunflower seeds					3	5	8
Coal dust		1,2	1,2	1,2	1,2	1,2	1,2

containing only clear clay was moulded for a comparison. The studied clay body compositions are presented in Table 1.

Raw materials and methods for analyses

Clay from Lucovite deposits (Bulgaria) was the main component of the ceramic bodies. The clay was initially crushed and ground to powder with particles of about 1 mm. The clay was characterized by chemical (ICP-AES) and XRD analysis using TUR-M62 diffractometer with CoKα radiation in the range of 2θ from 5° to 60°. The wheat straw and husks of sunflower seeds were crushed, ground and sieved to a maximum size of 0,5 mm. These biomasses were characterized by DTA/TG analysis using „Stunton Redcroft“ (England) in the temperature range 20°C-1000°C. The sample weight was 10,00 mg, while the heating rate was 10°C/min.

Samples preparation

The crushed clay and wheat straw or husks of sunflower seeds were mixed in a ball mill to enhance homogeneity. The required quantity of water was added to obtain the desired humidity and plasticity that are necessary to avoid structure defects during the process. The samples were extruded into a cylindrical form with a diameter of 40 mm and a height of 40 mm. They were dried at 105°C and finally fired at 900°C for 2 h.

Samples characterization

Properties such as apparent density, apparent porosity, thermal conductivity and compressive strength of the samples were determined. The Archimedes method was applied to determine their water absorption, apparent density and apparent porosity. The mechanical compressive strength of the fired ceramic products was determined with the application of a standard method using a hydraulic press. The thermal conductivity of the bricks was measured by the method of Ruk and Stallan based on heating of one of the ceramic sample sides and determining the time required for the other side to attain the same temperature. The device consisted of a tin container filled with water where an aluminum cylinder was immersed. The temperature control on the non-heated surface was carried out through a diphenylamine crystal having a melting point of 54°C - 55°C. The phase composition of the porous materials fired at 900°C was established by X-ray diffraction.

RESULTS AND DISCUSSION

Clay characterization

The chemical composition of Lucovite clay is given in Table 2. XRD data are presented in Fig. 1. Lucovite clay contains quartz, plagioclase, calcite, montmorillonite, illite and chlorite.

Biomass characterization

The thermogravimetric analyses of the biomasses prepared is illustrated in Fig. 2 and Fig .3.

The DTA and TG curves presented in Fig. 2 show

Table 2. Chemical composition of Lucovite clay.

Oxides, %	Clay Lucovite
SiO_2	64,19
Al_2O_3	8,07
Fe_2O_3	2,20
MgO	0,60
CaO	10,65
TiO_2	0,34
Na_2O	0,65
K_2O	2,21
IL	9,94

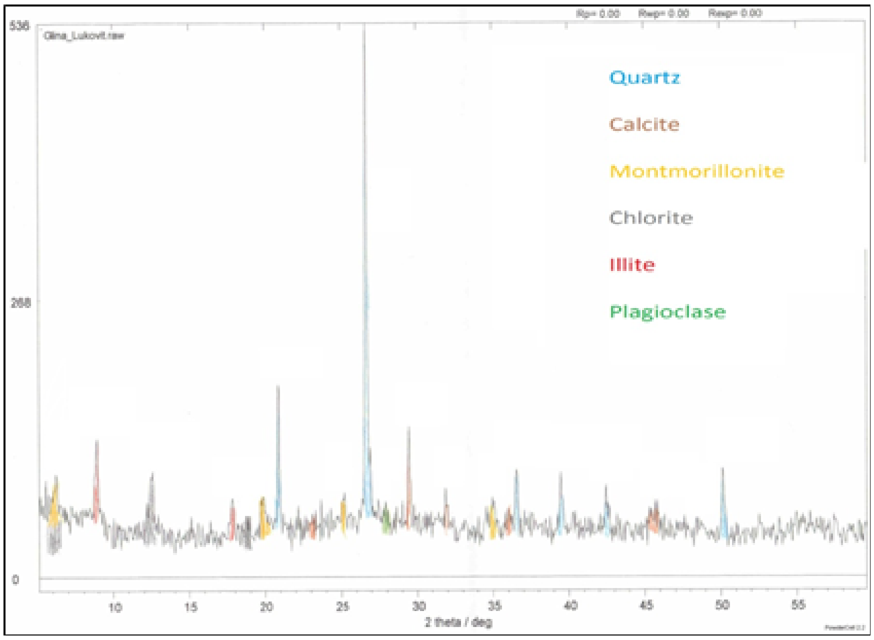

Fig. 1. XRD of clay Lucovite.

that a weight loss of ca 55 % is observed on heating the wheat straw to 350ºC, while a total weight loss of 90 % is reached on heating to 550ºC. Two exothermic effects are observed at 250ºC and 450ºC. They are related to the burning of wheat straw organic substances.

Fig. 3 shows that a weight loss of ca 43 % is observed on heating sunflower seeds husks to 330ºC. It is followed by a subsequent mass loss of 34 % on heating to 600ºC. Two exothermic effects observed - a small one at 300ºC and a larger one at 500ºC. They result from the decomposition of the organic compounds in the sunflower seeds husks.

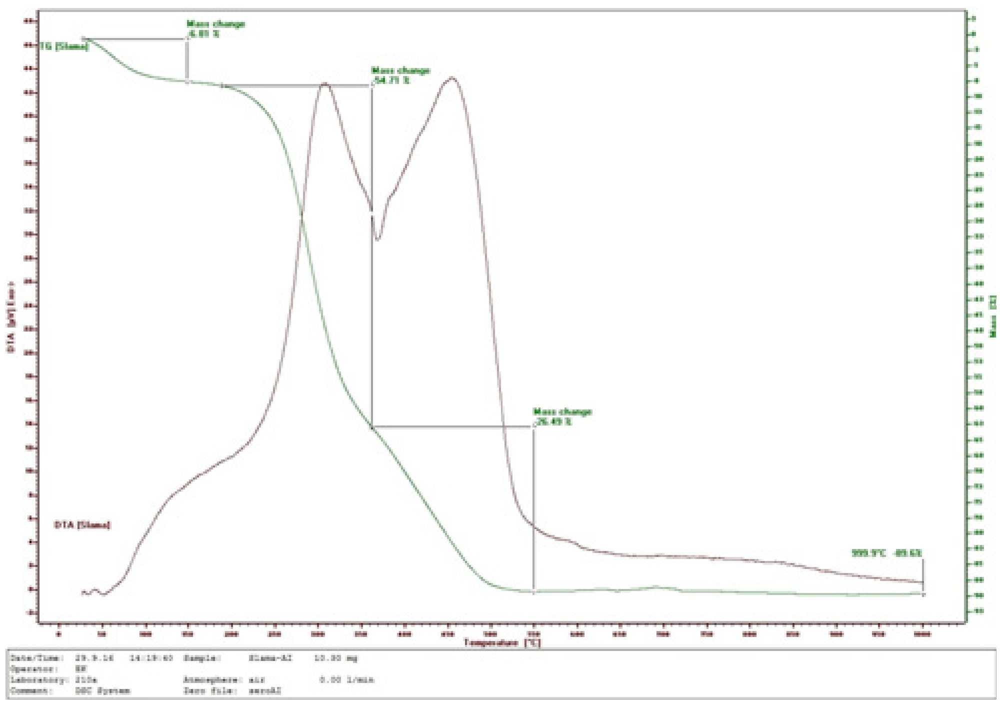

Fig. 2. DTA/TG of wheat straw.

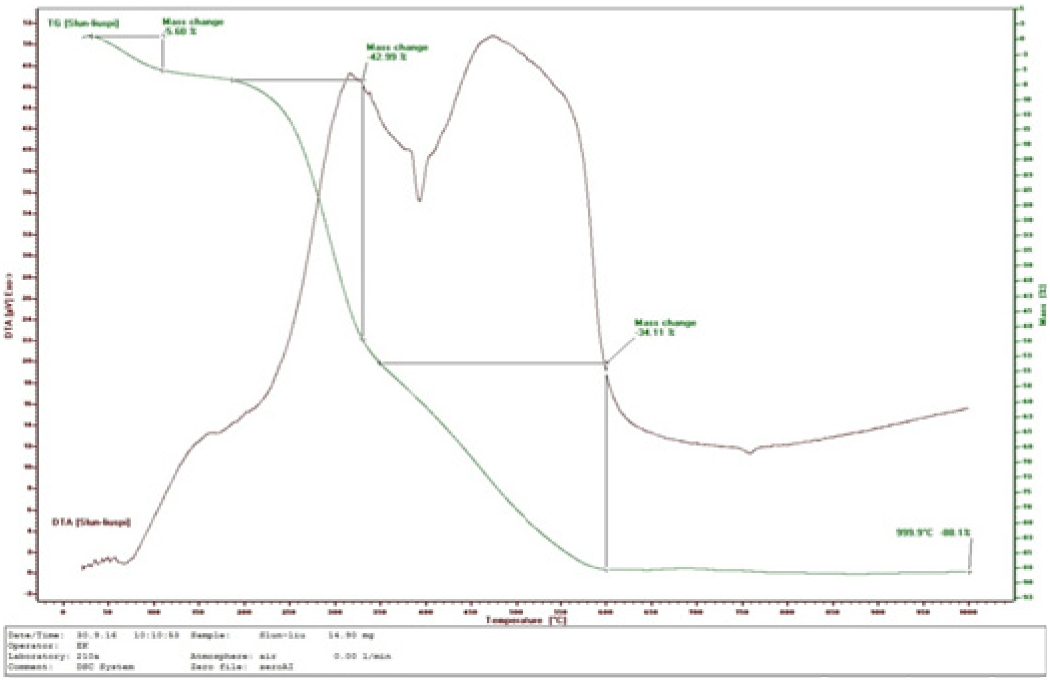

Fig. 3. DTA/TG of husks of sunflower seeds.

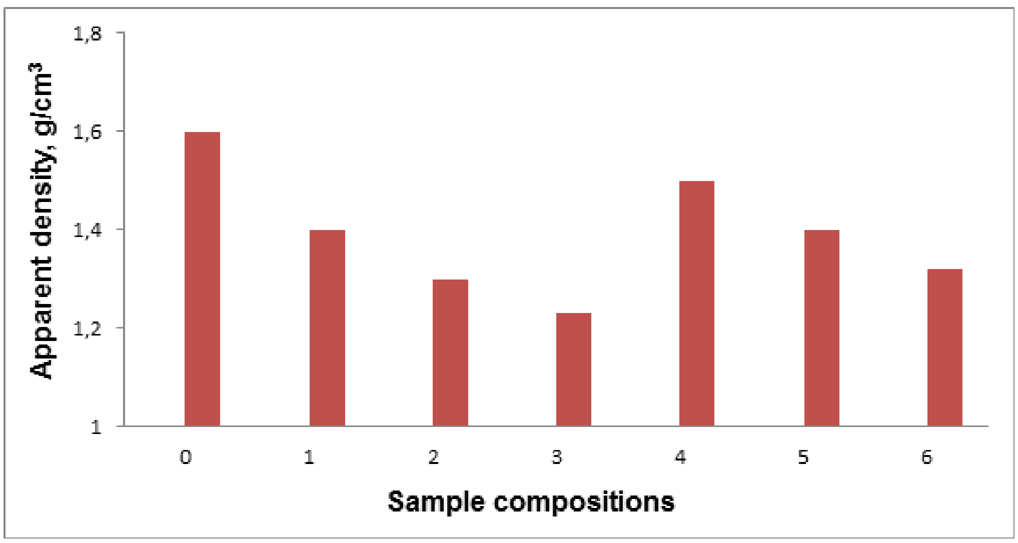

Fig. 4. Apparent density of porous clay samples fired at 900°C.

Properties and phase composition of the ceramic samples

The apparent density of the clay samples containing no additives is 1.6 g/cm^3. The apparent density of the fired porous samples decreases with the addition of biomass due to the increased number of pores created by combustion of the organic biomass compounds. Fig. 4 shows that the apparent density of the porous clay samples containing 8 mass % wheat straw is 1.23 g/cm3, while that of the samples containing sunflower seeds husks is 1.32 g/cm^3.

The values of the apparent porosity increases with the addition of biomass from 32 % for the sample with no pore-forming additive to 53% for the samples containing 8 mass % WS and 50 % for those cointaining 8 % mass % HSS. This is more than 50 % of the apparent porosity of the sample without additives. The addition of 8 mass % WS to the basic clay body decreases the thermal conductivity of the fired clay product from 1,0 W/m·K (for samples without an additive) to 0.5 W/m·K (a decrease of 50 %). The thermal conductivity of the clay brick sample decreases to 0,6 W/m·K in presence

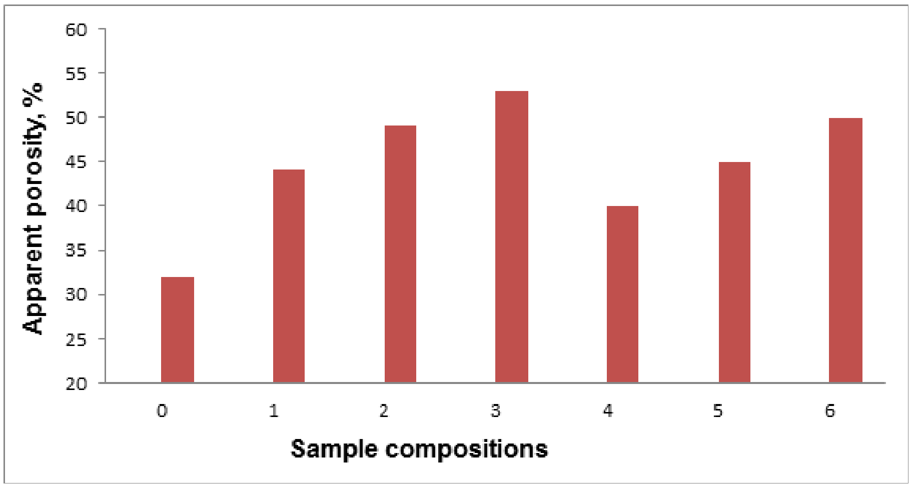

Fig. 5. Apparent porosity of ceramic porous samples.

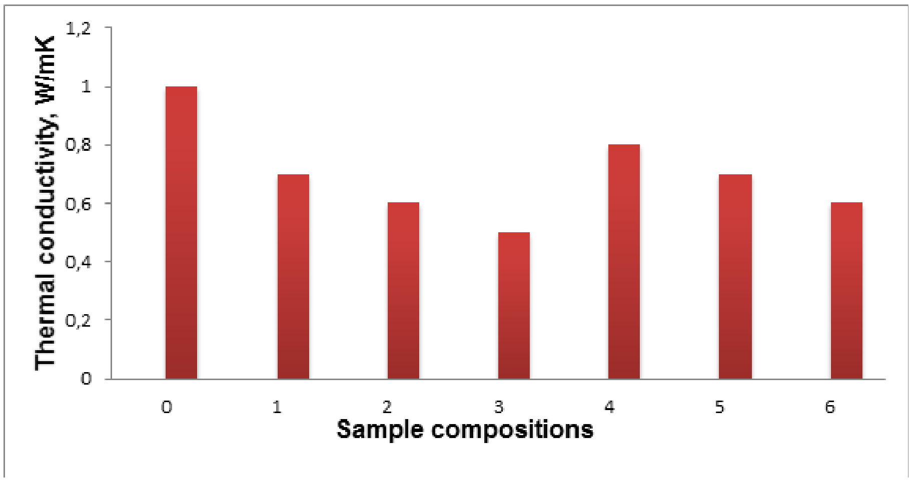

Fig. 6. Thermal conductivity of ceramic porous samples.

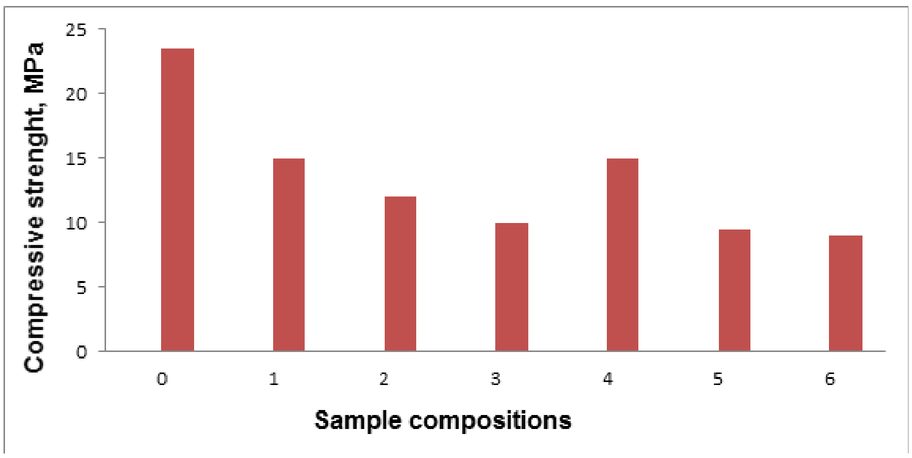

Fig. 7. Compressive strength of ceramic porous samples.

of WS additive of 5 mass %. A slight decrease of the thermal conductivity is observed in adding HSS. The compressive strength of the ceramic materials is the most important property of a building material. According to the standard, the bricks compressive strength must be 10 MPa [12]. The compressive strength decreases with increase of the amount of the biomass . It is less than the standard one in case of introduction of 8 mass % WS. The experiments show that the addition of 5 mass % of wheat straw to a porous clay brick body results in

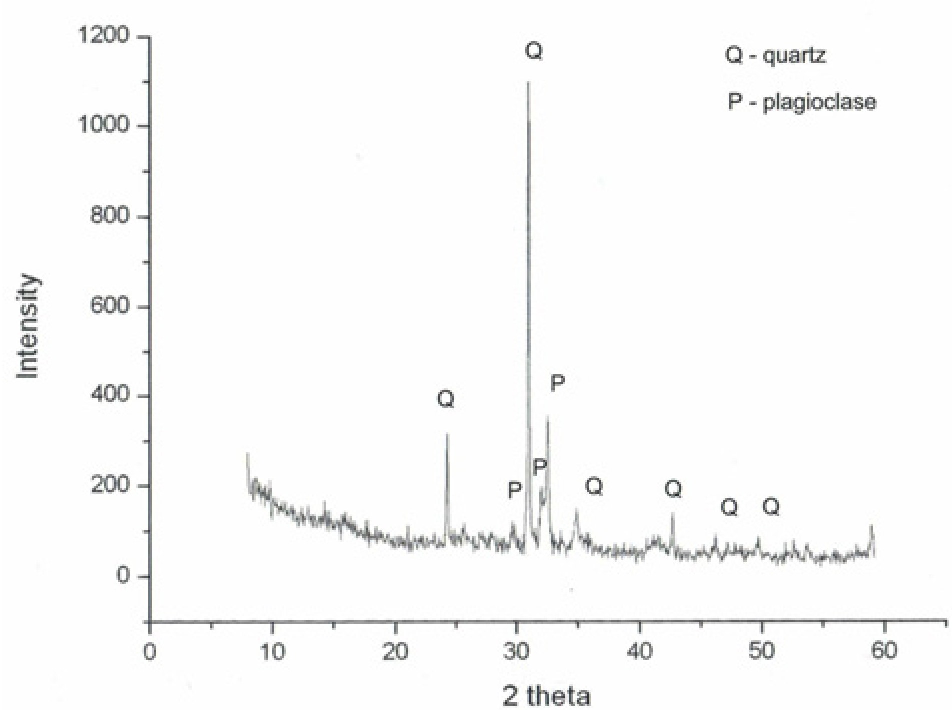

Fig. 8. Phase composition of fired at 900°C ceramic porous samples.

compressive strength within the standard values range. Additions of 5 mass % and 8 mass % husks of sunflower seed are not suitable for porous clay bricks as the mechanical strength data are below the standard limit. The recommended amount of sunflower seeds husks present in porous clay bricks refres to 3 mass %.

The phase composition of all sample determined by XRD analysis shows that quartz and plagioclase (anorthite) are present.

CONCLUSIONS

The effect of 3 mass %, 5 mass % and 8 mass % of wheat straw and sunflower seed husks on the properties of porous ceramic samples fired at 900°C is elucidated. Both biomasses studied can be effectively used for pore forming. The apparent density of the fired products decreases with the addition of biomass due to the increased number of pores created through combustion of the organic biomass matter, as indicated by the TGA–DTA curves. The increase of the amount of the pore-forming additive increases the porosity but decreases the thermal conductivity of the samples. The presence of up to 3 mass % of sunflower seed husks provides compressive strength which is standard for this type of pottery. An amount of 3 % sunflower husks in the composition of the light porous ceramic bricks is recommended. The presence of 8 mass % wheat straw decreases the compressive strength to the limit of the standard (10 MPa). A quantity of 5 % wheat straw is recommended because the thermal conductivity is reduced by 50 % when compared to that of a ceramic sample with no additive but the value obtained is greater than the standard one for this type of material.

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