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Lightweight Materials Obtained by Utilization of Agricultural Waste

Bogdan Bogdanov, Irena Markovska, Yancho Hristov, Dimitar Georgiev

***Abstract*—**Lightweight ceramic materials in the form of bricks and blocks are widely used in modern construction. They may be obtained by adding of rice husk, rye straw, etc, as porous forming materials. Rice husk is a major by-product of the rice milling industry. Its utilization as a valuable product has always been a problem. Various technologies for utilization of rice husk through biological and thermochemical conversion are being developed.

The purpose of this work is to develop lightweight ceramic materials with clay matrix and filler of rice husk and examine their main physicomechanical properties. The results obtained allow to suppose that the materials synthesized on the basis of waste materials can be used as lightweight materials for construction purpose.

***Keywords*—**lightweight ceramic materials, properties, agro-waste

I. Introduction

THE lightweight ceramic materials in the form of clay bricks and blocks are more widely used in modern construction. The way of its obtaining is to add in clay different porous forming agents - including rice husk, straw of rye and barley, etc. [1-3]. The usage of these combustible materials as porous forming agents for production of lightweight insulating bricks has two main advantages - the need for less energy due to the large amount of energy that is released during combustion byproducts. In the same time this is an alternative method for the efficient utilization of large amounts of waste materials [4-6]. The rice husk is a major co-product of rice manufacturing. Investigations showed that the interest towards rice husk is increasing worldwide. It is connected with the leading role of rice as a grain culture from which waste products cannot be used as food, fertilizer or fuel. In this aspect, the problem with the utilization of the large amounts of this material elimination of certain ecological threat remains to be solved [7-11]. A number of reviews have been dedicated to rice husk and the products obtained from its thermal degradation at different conditions [12-16].

Prof. Bogdan Bogdanov, Depertment of Silicate Tehnology, Prof. Dr. Assen Zlatarov University, Bourgas 8010, Bulgaria

Assoc. Prof. Irena Markovska, Depertment of Silicate Tehnology, Prof. Dr. Assen Zlatarov University, Bourgas 8010, Bulgaria, (e-mail: imarkovska@btu.bg)

Assoc. Prof. Dimitar Georgiev, Depertment of Materials Science, Prof. Dr. Assen Zlatarov University, Bourgas 8010, Bulgaria

Assistant prof. Yancho Hristov, Depertment of Materials Science, Prof. Dr. Assen Zlatarov University, Bourgas 8010, Bulgaria

The aim of this work is to develop lightweight ceramic materials from clay and rice husk, and to investigate the effect of varying rice husk and clay contents on the insulating properties of kaolin clay firebrick.

II. Experimental Section

A. Methods

The materials obtained were characterized by X-ray analysis, differential thermal analysis (DTA) and scanning electron microscopy (SEM).

The X-ray analyses were carried out by the method of powder diffraction using X-ray apparatus equipped with goniometer URD-6 (Germany) with cobalt anode and K_α emission.

The DTA experiments were performed on an apparatus for complex thermal analysis (STA 449 F3 Jupiter), NETZSCH – Germany.

The micrographs were taken using scanning electron microscope Tesla BS 340 (Czech Republic). The SiO_2 content in the solid residue was determined after treatment with hydrofluoric acid.

B. Materials

As the main raw materials were used:

i. Kaolin clay with impurities of iron and organic compounds, whose composition is given in Table II

ii. rice husk - the present study was carried out with rice husk obtained during processing of rice variety Krasnodarski 424 grown in Bulgaria. Before use, the rice husk were thoroughly washed – three times with tap water followed by three times with deionised water to remove adhering soil, clay and dust, boiled for an hour to desorbs any impurities and finally, dried at 100 ^{0}C overnight. The dried husk were ground in rotary cutting mill and sieved manually with 0.63–0.12 mm sieves. This starting material was used for all further studies.

TABLE I
OXIDE COMPOSITION OF CLAY

Oxide	Weight %
SiO_2	54.07
Al_2O_3	28.11
Fe_2O_3	2.15
TiO_2	1.16
Na_2O	0.90
K_2O	2.01
CaO	1.03
MgO	1.56
LOI	9.01

III. Results And Discussion

A. Studies on the rice husk

1. Derivatographic studies

The development of various technological methods for utilization of rice husk by thermal decomposition can not be accomplished without profound studies on the processes of their thermal destruction by DTA-analysis (fig.1). The present derivatographic studied were carried out under the following conditions:

i. in static air, under heating, first the physically adsorbed water was released (5%), followed by the burning of the organic components to obtain solid residue (26% residue containing mainly SiO_2 - 91,6%).

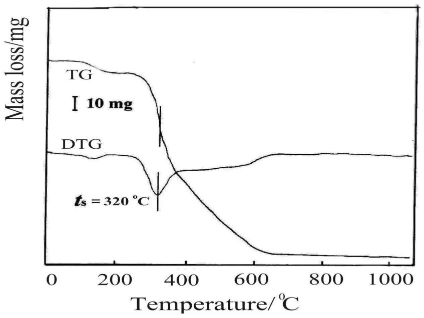

Fig. 1 DTA and TG curves of RH samples burning in air

It is known [12-14] that the thermal destruction of rice husk has three stages: drying (40-150°C), removal of volatile organic components (215 – 350°C) and burning of carbon (350-690°C). From thermogravimetric calculations based on the data obtained from DTA, the kinetic characteristics of the destruction processes can be determined, as it has been already reported earlier [15,16]. The DTA analysis of rice husk treated in oxidative medium (Fig.1) showed that the physically adsorbed water was released in the temperature interval 80°C – 180°C which was indicated by the 5% mass loss. The process of thermal destruction began at 220°C and ended at 640°C with 74% mass loss. The mass loss at 270°C was 10% and at 430°C – 50%. The processes of thermal destruction proceeded with maximum rate at 320°C in air and 360°C in nitrogen.

2. X- ray analysis

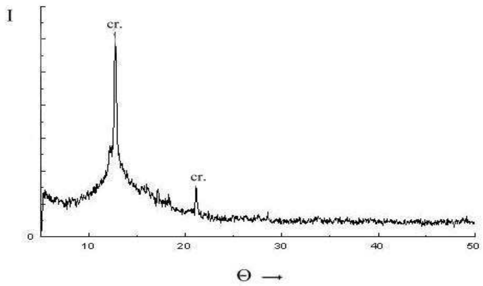

Fig. 2 X- ray analysis of rice husk, thermally treated in air at 900 ^{0}C

Since the raw and the thermally treated rice husk can be used as components in composite materials, it is important to know what structure changes they undergo during heating. The determination of the temperature up to which the powder is amorphous is significant because the crystalline product has lower reactivity than the amorphous one. The diffractogram of sample oxidized at 900°C presented in fig. 2 shows a strong peak (*d* = 4.06 Å) corresponding to the high - crystalline phase of silica - α-cristobalite, and distinguishable peak at d = 2.48 Å (characteristic also for α-cristobalite). Quartz was not detected. The rice husk used in our work, were heated in oxygen medium in the temperature range 400 - 1000 °. For the purposes of these experiments have been chosen RH burned at 600 °. According to X-ray analysis carried out at temperatures around 600 ° C, silicon oxide in rice husk is still in active the amorphous form, which combined with the porous structure of the ash makes it very reactive in the process of sintering the samples.

B. Studies on the clay

The mineralogical composition of clay is determined by the X- ray analysis. The main phases observed were: quartz, kaolinite, feldspar and magnetite. Fig. 3 shows DTA and TG curves of the clays. The DTA of clay carried out shows that wide endo- effect at about 110 ^{0}C can be seen due to the release of water-related natural kaolin, which is accompanied by about 1% weight loss. At 340 ^{0}C exo-effect appears due to the presence of minerals magnetite, which is accompanied by about 1, 15% loss in weight, it is followed by a wide endo-effect at about 540 ^{0}C, due to the collapse of the clay materials and chemical separation related water in the clay, which is associated with about 6% weight loss. At about 950 ^{0}C exo-effect reappears which may be associated with the processes of formation of new phases. This process is accompanied by with 1, 20% weight loss.

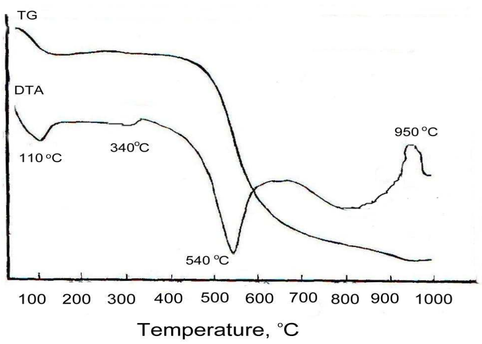

Fig. 3 DTA and TG curves of clay

Technological properties of clay materials mainly depend on their degree of dispersion [17]. Granulometric composition of clay affects the number of properties such as density, compressibility, porosity, etc. Through the sieve analysis the granulometric composition of clays was investigated.

The results show that the largest amount is a fraction with particles size less than 63 µm. Distribution of particles in the clay fractions are given in Table II.

TABLE II
GRANULOMETRIC COMPOSITION OF CLAY

Particle Size, µm	Fraction, %
≥ 500	1
500 - 125	8
125 - 63	10
≤ 63	81

It is known that the grain composition of the clay plays an important role on the frost resistance [17]. Data from the definitions of grading of clay used are a prerequisite for high frost resistance of bricks made from it.

C. Studies on the clay materials with addition of rice husk

Based on a clay matrix and thermally treated or raw rice husk 11 kinds of samples were synthesized which composition is given in Table 3. The specimens were formed by semi-dry pressing on hydraulic press "Carl Zeiss Yena" (Germany). Brick were dried to approximately 5-7 % moisture content. The dried brick were finally fired in a furnace at temperature of 1000 ^oC. This firing process caused the burning out of the rice husk in the finished bricks.

TABLE III
COMPOSITION OF THE SAMPLE, WT.%

№	Clay	Raw rice husk	WRHA
1	100	-	-
2	99	2	-
3	98	3	-
4	97	4	-
5	96	5	-
6	95	6	-
7	99	-	3
8	98	-	4
9	97	-	5
10	96	-	6
11	95	-	7

Fig. 4 presents electron-scanning microphotograph of the sample № 9 with clay matrix reinforced with WRHA.

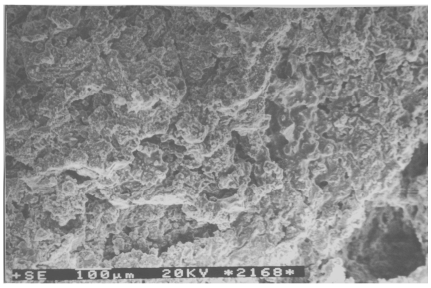

Fig. 4 Electron-scanning microphotograph of sample

Data from X- ray analysis showed that the main phases observed are: quartz, kaolinite, feldspar and magnetite. Some of the main physico-mechanical properties of the synthesized samples as density, water absorption and porosity are measured. The results are presented in Table IV.

TABLE IV
PROPERTIES OF SAMPLE BASED ON CLAY AND WRHA

Composition	Apparent density, ρ x 10^{-3} kg/m^3	Water uptake, %	Porosity, %
1	1.72	21.60	37.13
2	1.63	22.25	37.60
3	1.61	24.90	40.44
4	1.56	26.92	41.93
5	1.53	27.81	43.85
6	1.47	29.71	45.11
7	1.69	22.10	37.21
8	1.63	24.60	39.75
9	1.60	26.10	41.22
10	1.56	27.29	42.59
11	1.53	27.81	42.85

The results show that the density of the synthesized material ranges from 1.70 to 1.53 g/cm^3, and their water absorption is within 22 to 28%. The density decreases with increasing the addition of rice straw and rice husk ash in the brick, while the apparent density and water absorption increase. This fact may be connected with large losses in ignition, which was in rice straw about 80%, and in ash from rice husk - 16%.

In general, the parents synthesized from clay and white ash have better physico-mechanical properties compared to those synthesized from clay and rice straw. The results of the analysis showed that the selected clay can be used for making of hollow insulating bricks.

IV. CONCLUSIONS

Based on rice husk and clay matrix a number of lightweight ceramic materials were developed. Rice husk - raw and thermally treated contribute to the formation of porous structure in the samples. Synthesized materials are with porosity ranging from 37 to 43%. Using the rice husk, burned at 600 ° C in air, silicon oxide in rice husk is still in the active amorphous form, so combined with the porous structure of the ash makes it very reactive in the process of sintering the samples.The main phases contained in fired bricks are: quartz, kaolinite, feldspar and magnetite. The samples obtained from clay and ash have higher physical - mechanical properties compared to those synthesized from rice straw and clay.

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