*INTERNACIONALNI NAUČNO-STRUČNI SKUP*
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# THE INFLUENCE OF SUPPLEMENTS ON THE QUALITY OF THE PRODUCTS IN BRICK INDUSTRY

***Abstract***

The main objective of this study is to investigate the potential utilization of some organic additives in clay bricks. It is examined the effects of adding soy crust, wood cutting and coal dust on both durability and mechanical properties of the bricks. In the first set the additives were added and the second set was used for comparing. The main conclusion is that these materials can be used in the above mentioned process.

***Key words***

supplements, masonry industry

# UTICAJ ADITIVA NA KVALITET PROIZVODA U CIGLARSKOJ INDUSTRIJI

***Rezime***

Cilj ovog rada bio je ispitivanje potencijala primenljivosti određenih sekundarnih sirovina kao aditiva u ciglarskoj industriji. Konkretno, ispitivani su efekti dodatka sojinih ljuspica, piljevine i ugljenog taloga u ciglarsku masu. Tokom testiranja je zaključeno da se korišćeni materijali mogu primeniti u industriji za proizvodnju opekarskih proizvoda jer se njihovom primenom štiti životna sredina i poboljšavaju izolaciona svojstva ovih proizvoda.

***Ključne reči***

aditivi, ciglarska industrija

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# 1. INTRODUCTION

Worldwide, the clay is the main raw material in fabrication process of different ceramic products. Due to inherently complex physical, chemical and mineralogical characteristics, the clay has usually unique properties related to its own natural diagenesis [1].

Bricks have been used over 5000 years as a construction material throughout the world. Today, they are still being used for the same purpose. As urbanization expands, demand for bricks gradually increases [2]. Environmentally friendly, energy saving recycle property of material production has been one of the very important research fields. One of the ways to increase the insulation ability of bricks is generating porosity in brick body. Combustible organic types of pore-forming additives are most frequently used for this purpose. These substances are used to improve brick porosity, while decreasing drying time and firing energy consumption. This leads, to reduction of both products volume mass and thermal conductivity to occur [1]. The main problem which occurs is that adequate circumstances for organic material addition are not always present. Namely, the bulk with improved porosity must satisfy also rigid plasticity requirements. Besides, there is always possibility for over-loading the clay with additives, so it can cause uncontrollable firing [3, 4].

The main objective of this study is to investigate the effects of soy crust, wood cutting and coal dust material addition on the properties of unfired and fired building bricks.

# 2. EXPERIMENTAL

## 2.1. POROSITY INCREASING METHOD

Hollow bricks with increased porosity do not differ in appearance, shape and embedment site from traditional products and it can be used in the same way as traditional bricks. When fervid pulverous (powder) components are added to raw clay bulk, upon firing, more porous product is appeared. Many different materials can be used as burnable materials such as: expanded polystyrol balls (with 2.5 mm radius), squashed olive residues, seeds skin, wood cutting, rice weeds, coal dust etc. After added of chosen material, the mass must be homogenized, and water must be added ant than the plastic product is shaped, dried and fired.

Level of porosity depends on particles density and loss of ignition caused by firing additives, which can vary on water content and gross density. As water absorption capacity growth, more water is needed in order to get uniform mass. These mixtures contained much more water then basic mineral raw material. It is also important to note that drying shrinkage of basic raw material is much higher then for additives alone [4-6].

In order to produce test samples, the clay was taken from raw material stockpiled in several production areas in Serbia. In this work the used additives are coal dust, Soy crust and wood cutting.

### 2.1.1. Coal dust

Dust is added in different ratios to clay. The clay was taken from two localities (composites marked with 1 and 2, and 3 and 4). The Coal dust volume mass is 1.191 g/cm$^3$. Humidity determined after drying at 105°C to constant mass is 51.80 %. All coal dust particles were under 2 mm radius. Mass percentage of added coal dust was 3 and 6 % for every taken sample. Coal dust which is used in experiments was a residue after coal washing in industrial tanks.

### 2.1.2. Soy crust and wood cutting addition

Industry waste wood cutting is traditionally used as pore forming additive. When wood cutting is used to improve porosity, it is recommended to add about 15 vol % to get approximate density of 1.50 kg/m$^3$ [4].

Composites marked with 5 and 6 are made of raw clay material taken from a third locality with separate addition of ground soy crust and wood cutting. Volume masses of soy crust and wood cutting are 0.388 g/cm$^3$ and 0.161 g/cm$^3$, respectively. Additive contents were 15 vol % for both examined samples.

## 2.2. PREPARATION OF SAMPLES

Testing samples were manufactured using standard pilot laboratory procedures and equipment. Test samples (plates 120 x 50 x 14 mm, no perforation cubes 30 x 30 x 30 mm and hollow bricks 55.5 x 36 x 36 mm) were shaped with a laboratory-type Händle extrusion machine. Shaped samples were dried at laboratory conditions for 72 hrs and kept in an oven at 105±5°C until constant weight was obtained. Drying shrinkage of the samples was measured. All types of samples were fried at three different temperatures. Unfired samples were examined as well. Samples were heated at average rate of 1.4°C/min until 610°C and then at medial value of 2.5°C/min to final temperature. The specimens remained in the furnace at the maximum temperature for 2 hrs. The samples were cooled at room temperature in the furnace. After firing, shrinkage of the samples was measured. Fired samples colors vary from bright to brick red. For every composite, one group of samples is made.

# 3. RESULTS AND DISCUSSION

Defects were not observed after drying. Cracks, bloats and other firing defects were not observed after firing.

DTA and TG analysis were done at the interval from room temperature to 900°C, in platinum tank and dynamic nitrogen atmosphere with 100 cm$^3$/min flux. Heating speed was 20°C/min, and samples were between 11 and 15 mg.

Samples marked with 1, 2, 3 and 4 show very similar behavior. Water loosing begins at room temperature. Thermal effects which are not linked to water loss occur between 300 to 600°C, but they are practically negligible. Also, at 573°C one endothermic smoother peak occurs which is linked to $\alpha - \beta$ quartz conversion.

DTA curves of samples 5 and 6 show extremely weak endothermic effects. Much more sharp effects are observed at TG and DTG curves. While heating from room temperature to 200°C, DTA curve shows slope as water loss consequence. TG and DTG curves show smectite type of a clay (diagram elbows). These effects show total loss of 3.5 mass %. At the interval from 200 - 400°C, we can see 3 mass % losses. This kind of great loss shows that there is high content of organic materials or iron hydroxide. This is necessary to be checked doing chemical tests. At 400 - 600°C interval (weight loss of 2.8 %) is connected to clay mineral endothermic effects. At 600 - 800°C interval 5-6 % loss is actually calcite loss.

While firing bricks with organic supplements, some processes are improved by occurrence of pyrolitical reactions. Gasses released during carbonization/pyrolysis burn themselves within product or in a furnace atmosphere. As long as energy released by process described above is below 400 KJ/kg, this energy partly compensates fuel consumption. In some cases where additives are added in larger quantity, products have considerable caloric values, which cause firing curves deformation. In these cases products easily burst, so there is always a risk that this energy could not be controlled in the furnace.

Mechanical characteristics of all examined composites are shown in Tables 1 – 3.

*Table 1. Mechanical characteristics of composites 1 and 2*

| Composite 1 characteristics (Coal dust addition of 5 vol %) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Firing Temperature (°C) | Loss of Ignition (%) | Firing shrinkage (%) | Total shrinkage (%) | Water absorption (%) | Compressive Strenght (MPa) | | Volume Mass (g/cm$^3$) |
| | | | | | cb | hb | |
| 870 | 6,33 | -0,11 | 7,90 | 11,61 | 53,78 | 20,35 | 1,80 |
| 900 | 6,47 | 0,20 | 7,90 | 11,34 | 57,91 | 24,61 | 1,85 |
| 950 | 6,59 | 0,55 | 8,35 | 10,36 | 72,48 | 30,25 | 1,89 |
| Composite 2 characteristics (Coal dust addition of 10 vol %) | | | | | | | |
| Firing Temperature (°C) | Loss of Ignition (%) | Firing shrinkage (%) | Total shrinkage (%) | Water absorption (%) | Compressive Strenght (MPa) | | Volume Mass (g/cm$^3$) |
| | | | | | cb | hb | |
| 870 | 7,49 | 0,03 | 8,11 | 12,10 | 51,69 | 19,95 | 1,76 |
| 900 | 7,51 | 0,12 | 8,09 | 11,73 | 56,56 | 21,12 | 1,77 |
| 950 | 7,64 | 0,47 | 8,28 | 10,96 | 65,29 | 27,45 | 1,79 |

The obtained results show characteristic behavior when more or less *coal dust* is added. Samples with less coal dust quantity show less loss of ignition values (LOI), lower shrinkage and higher compressive strength values. With temperature increasing, shrinkage and compressive strength values mainly increased, but water absorption quantity decreased. *Soy crust* samples show higher LOI and water absorption values, and lower shrinkage and compressive strength values, when compared to wood cutting samples. Generally, the greatest observed LOI values are of soy crust samples, then wood cutting samples, and the lowest values are found in the case of coal dust samples [5, 6].

*Table 2. Mechanical characteristics of composites 3 and 4*

| Composite 3 characteristics (Coal dust addition of 5 vol %) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Firing Temperature | Loss of Ignition | Firing shrinkage | Total shrinkage | Water absorption | Compressive Strenght (MPa) | | Volume Mass |
| (°C) | % | (%) | (%) | % | cb | hb | (%) |
| 870 | 6,58 | -0,02 | 7,77 | 12,06 | 51,51 | 20,20 | 1,87 |
| 900 | 6,75 | 0,18 | 7,76 | 11,74 | 55,82 | 22,36 | 1,88 |
| 950 | 6,92 | 0,52 | 8,10 | 11,03 | 59,14 | 25,45 | 2,00 |
| *Composite 4 characteristics (Coal dust addition of 10 vol %)* | | | | | | | |
| Firing Temperature | Loss of Ignition | Firing shrinkage | Total shrinkage | Water absorption | Compressive Strenght (MPa) | | Volume Mass |
| (°C) | % | (%) | (%) | % | cb | hb | (%) |
| 870 | 7,47 | 0,03 | 7,88 | 12,48 | 47,75 | 19,13 | 1,82 |
| 900 | 7,54 | 0,10 | 7,81 | 12,22 | 50,30 | 20,47 | 1,82 |
| 950 | 7,56 | 0,33 | 7,96 | 11,58 | 56,99 | 23,69 | 1,83 |

*Table 3. Mechanical characteristics of composites 5 and 6*

| Composite 5 characteristics (Soy crust addition of 15 vol %) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Firing Temperature | Loss of Ignition | Firing shrinkage | Total shrinkage | Water absorption | Compressive Strenght (MPa) | | Volume Mass |
| (°C) | % | (%) | (%) | % | cb | hb | (%) |
| 900 | 9,9 | 0,26 | 7,50 | 15,27 | 44,29 | 22,27 | 1,62 |
| 930 | 10,1 | 0,47 | 7,64 | 14,92 | 48,39 | 24,82 | 1,63 |
| 950 | 10,2 | 0,49 | 7,68 | 13,95 | 49,08 | 26,36 | 1,64 |
| Composite 6 characteristics (Wood cutting addition of 15 vol %) | | | | | | | |
| Firing Temperature | Loss of Ignition | Firing shrinkage | Total shrinkage | Water absorption | Compressive Strenght (MPa) | | Volume Mass |
| (°C) | % | (%) | (%) | % | cb | hb | (%) |
| 900 | 8,2 | 0,08 | 7,27 | 13,04 | 50,02 | 25,75 | 1,72 |
| 930 | 8,2 | 0,30 | 7,48 | 12,38 | 51,10 | 26,90 | 1,74 |
| 950 | 8,3 | 0,37 | 7,52 | 11,86 | 56,12 | 28,00 | 1,74 |

## 4. CONCLUSIONS

Based on the experimental investigation reported in this paper and used literature, the following conclusions are drawn:

Constitution of the waste does not create any problem during shaping of products. Extrusion defects were not observed.

Black coring and bloating are not observed after firing.

DTA and TG analysis show increased organic (combustible) material content. At temperatures interval 200 to 400° C significant weight loss is observed.

According to test results, a mixture up to 6% coal dust additives and 15vol% wood cutting and soy crust additives can be used in brick production. The most economical firing temperature is up to 900°C. The use of organic waste in brick production provides an economical contribution and also helps the protection of the environment, which is very important.

Addition of supplements, decreases volume mass, decreases energy consumption while firing. - All examined supplements can be used as an organic kind of pore-forming additive in the clay body without any harmful effect on the other brick manufacturing parameters.

The waste additives increase the open porosity and this effect decreased the bulk density and improved the thermal insulating properties. Also compressive strentgh is decreased to acceptable values.

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