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Eco-friendly fired clay brick manufactured with agricultural solid waste

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ABSTRACT

Green building materials have attracted attention recently due to sustainability issues. Agricultural waste used as alternative raw materials in the manufacturing of building products, fired clay bricks in particular, is an innovative way of waste utilisation. Large quantities of waste are produced in grain processing. New ways of utilising this waste are required for solving this problem. The main objective of this study is to investigate the effects of agricultural solid waste (oat husk and barley husk and middlings) on the physical and mechanical properties and porosity of fired clay bricks. Brick moulding compounds were prepared by adding 5%, 10% and 20% of oat husk or barley husk and middlings and fired at 900 °C and 1000 °C temperature, keeping them at the highest temperature for 1 h. Oat husk, barley husk and middlings incinerate at 500 °C temperature, thus forming a porous structure in the clay body. The addition of 5–10% of oat husk or barley husk and middlings into brick moulding compound produces eco-friendly fired clay brick having the density of 1300–1800 kg/m^3, compressive strength of 3.3–9.5 MPa, total open porosity of 34–49%, water absorption 14–28%. Oat husk or barley husk and middlings reduce the compressive strength of eco-friendly fired clay brick.

1. Introduction

Eco-friendly building materials are gaining popularity and this industry is growing rapidly. The main factors influencing the growing popularity of eco-friendly building materials are as follows: environmental regulations, impact on the environment and human health, decarbonisation objectives and utilisation of materials at the end of the life-cycle. Fired clay bricks is one of the oldest and the most ecological building material as it is made of natural raw materials, namely clay, sand and water. Such products have high density, compressive strength, resistance to freeze–thaw cycles, and low water absorption values. Various combustible materials, which incinerate during firing, can be added to brick moulding compounds to obtain products of lighter weight, higher porosity and with low heat transfer coefficient [1].

Combustible agents form pores in clay brick [2], consequently, they change the structure of a product. Depending on

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the amount of combustible agent added and the highest temperature, mechanical properties of clay brick may considerably decrease [1].

Authors [3] suggest adding 10% of olive mill waste in clay brick and burn it at 950 °C temperature. The density of such products is 1.45 g/cm^3, thermal conductivity – 0.436 W/mK, compressive strength – 10 MPa, porosity – 47%. Other authors [4] claim that up to 5% of processed waste tea improve physical–mechanical properties of clay brick that is burn at 900 °C temperature, and the lower amount of additive negatively affects the strength properties.

Natural grain by-products can be used as combustible agents [5–7]. Authors [5] state that under addition of 10% of rice husk, the density and compressive strength of the products deteriorate, water absorption increases.

Grain processing generates a lot of by-products, such as husks, mixtures of husk and middlings, etc. During grain threshing season the mill may generate up to 4–5 tons of husks and up to 2–3 tons of hull and middlings mixture. Modern facilities usually use grain processing waste (humidity $< 10\%$) as biofuel for boiler rooms [8,9]. Smaller companies, however, do not have such possibilities and incur high waste transportation and landfill costs. In terms of economy, the most beneficial approach is to use grain processing waste as animal feed. Unfortunately, stale or rotten grain processing by-products cannot be used to this end.

Agricultural solid waste incinerated in boiler rooms generates large amounts of ash that must be utilised. Chemical composition and characteristics of this ash differ depending on the region where crops, used as agricultural solid waste, were grown and also on the firing temperature. It was found [10,11] that clay bricks produced from clay containing rice husk ash additive, fired at 1000 °C temperature and conditioned for 4 h have higher firing shrinkage and compressive strength. The bricks are recommended for load-bearing walls. Other authors [12] argue that in order to obtain high performance clay brick products, the firing temperature must be increased to 1050 °C, whereas the optimum rice husk ash content is up to 30%. Authors [6] say that the optimum rice husk ash content in the ceramic body may not exceed 2%. The density of such products reaches 1.68 g/cm^3, the compressive strength is 6.2 MPa, and water absorption is 15.2%. Higher content of ash has a negative effect on the strength properties of ceramic products. Authors [13,14] tested the effect of sugarcane bagasse ash and propose to add it at 10%. Other authors [15] state that sugarcane bagasse ash can be increased up to 20%. The firing temperature must be at least 1000 °C. In temperatures above 1000 °C, the ash reacts in the liquid phase and causes the formation of new phases (mullite and cristobalite).

Agricultural solid waste can be used as combustible additives that may have a positive effect on the ceramic body's properties depending on the origin and characteristics of the additive, content in the mix and the firing temperature of the clay body. Tests conducted by researchers [5] proved that up to 10% of combustible rice husk can be added to the clay brick mix in order to meet the requirements of standard EN 772-1. The strength of such clay bricks ranges between 7 and 10 MPa. Some authors [7] argue that up to 50% of rice husk can be added to the clay brick mix. Authors [16] found that 5% of grape and cherry seed additive has a better effect on physical and mechanical properties of the ceramic body compared to wood sawdust additive.

Secondary research showed that the use of organic grain waste in the manufacturing of ceramic products is well examined, but the effect of agricultural solid waste on the final properties of ceramic products differs depending on the crop harvesting region, grain properties, the properties of core materials (clay, sand), firing temperature and additive content in the mix. There is also a great variety of agricultural solid waste.

In the context of recycling, the present study focuses on using agricultural solid waste (oat hulls, barley husk and meal mixture) in clay brick compounds for civil construction. Although the ceramic industry is highly promising for the final disposal of solid wastes, little is known about the reuse of agricultural solid waste (oat husk, barley husk and middlings) in clay ceramics.

The main objective of this study is to investigate the effects of agricultural solid waste (oat husk and barley husk and middlings) additives on physical and mechanical properties and porosity of fired clay bricks.

2. Materials and methods

The experiments were done with clay of low melting point, sand, and oat and barley processing by-products: oat husk, and barley husk and middlings.

At first the components were dry-mixed and afterwards they were wetted to the humidity required for moulding (20–25%). Plasticity is an important parameter in clay brick manufacturing. Insufficient plasticity may cause heterogeneities of the moulding mass and result in weaker mechanical properties. Tests revealed that higher content of OH and BHM additives increase the water demand to obtain the moulding compound of adequate plasticity. The reason is high water absorption of organic components. 70 × 70 × 70 mm specimens were formed from the moulding compound. 12 specimens were made out of each moulding compound. 6 specimens were fired at 900 °C temperature and 6 specimens were fired at 1000 °C temperature. The compositions of the moulding compounds are shown in Table 1. The specimens were kept for three weeks under natural laboratory conditions; afterwards they were dried to the constant mass at 105 ± 5 °C temperature. Dried specimens were fired at 900 °C and 1000 °C temperatures and conditioned for 1 h at the highest firing temperature.

The block diagram below (Fig. 1) illustrates the methodology followed in the manufacturing of clay bricks (brick specimens) containing agricultural solid waste.

The chemical composition of the raw material used in laboratory tests was analysed by applying the classical chemical analysis methods for silicate materials and by using energy-dispersive detector (INCA PENTA FET 3, Oxford Instruments, Co., UK). The compressive strength of the ceramic body was measured following the procedure described in LST EN 772-1:2003, net dry density was measured according to LST EN 772-13:2003, water absorption (W_h) according to EN 772-21:2011, initial rate of absorption according to LST EN 772-11:2011. The effective and total porosity of

Table 1 – Composition of moulding compounds.

Raw materials	Composition of moulding compounds (%)						
	CS	OH5	OH10	OH20	HBM5	BHM10	BHM20
Clay	90	85	80	70	85	80	70
Sand	10	10	10	10	10	10	10
Oat husk (OH)	0	5	10	20	0	0	0
Barley husk and middlings (BHM)	0	0	0	0	5	10	20

ceramic bodies was measured according to the methodology described by authors [17]. Micro-structure tests and EDS analysis was done with the scanning electron microscope Quanta 250 equipped with SE detector.

The drying shrinkage and firing shrinkage were calculated from the equations below (Eqs. (1) and (2)).

$$L = \frac{L_0 - L_1}{L_0} \times 100\% \tag{1}$$

$$L_B = \frac{L_0 - L_2}{L_0} \times 100\% \tag{2}$$

where L_0 is distance between markings in the wet specimen, mm; L_1 is distance between markings in the dried specimen, mm; L_2 is distance between markings in the fired specimen, mm.

The two-sided confidence intervals with the confidence level of 0.95 of the measured quantities (porosities, shrinkage, density, water absorption, strength) were calculated by assuming that the samples are distributed according to the Normal law, and the Student distribution was applied for the calculation of the confidence intervals: $(m - t_{d,(1-\alpha/2)}{}^{\cdot}s/\sqrt{n}) \le \mu \le (m + t_{d,(1-\alpha/2)}{}^{\cdot}s/\sqrt{n})$, where m, s and $n = 6$ are estimations of mean, standard deviation and sample size respectively, $t_{d,(1-\alpha/2)} \approx 2.57$ is $(1 - \alpha/2) = 0.975$ quantile of the Student distribution, where $\alpha = 0.05$ is the level of significance and $d = n - 1 = 5$ is the degree of freedom. Numbers written in format $m \pm \Delta$ in figures and tables of the present article represent the values of the corresponding sample means, letter m, and deviations of the limits of the confidence intervals of the porosities $\Delta = t_{d,(1-\alpha/2)}{}^{\cdot}s/\sqrt{n}$.

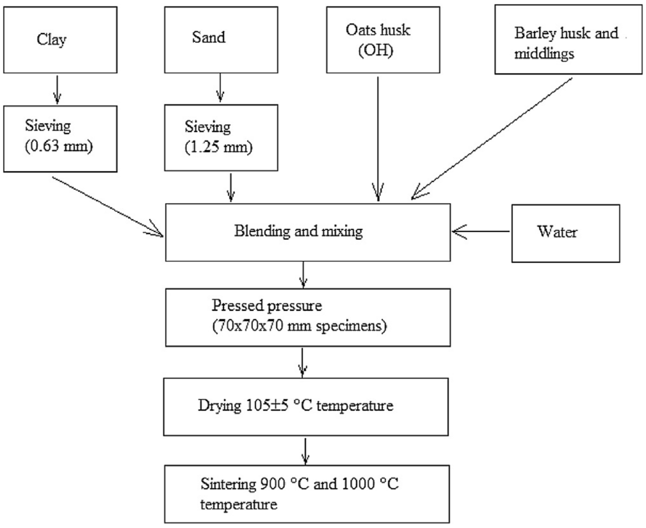


Fig. 1 – Clay brick (brick specimen) manufacturing methodology.

3. Results and discussion

Test results showed that Al_2O_3 content in the clay used for the tests is 19.53%, the content of SiO_2 is 63.56%, and the content of colouring oxides Fe_2O_3 is 6.55%. The content of the fluxing oxides, such as K_2O, Na_2O and CaO is 7.12% (Table 2). According to particle-size distribution, the clay is a dispersible material because the content of 0.01 mm-sized particles is more than 75%. Clay plasticity especially depends on the particle-size distribution [18,19]. Finer grained clay is more plastic due to larger particle contact surfaces and stronger cohesive forces (Table 3). The data of clay plasticity illustrate that the clay used for the tests belongs to semi-plastic clays with the average plasticity value of 19.3. The natural humidity of clay is 18.6%, and the density is 2.42 kg/m^3.

The analysis of clay microstructure is presented in Fig. 2. The clay particles are plate shaped and distributed evenly. Clay particles contact with particles of other substances via thin clay particle bridges; particulate debris is present among clay plates, plate size range is 2–11 μm.

Oat husk is made of rather big-size particles ranging from 0.5 to 1.00 mm, there are traces of particulate debris, the bulk density is 0.21 g/cm^3. The mixture of barley husk and middlings is made of 0.3 mm particles and mill by-products of 0.215–0.63 mm size, the bulk density is 0.27 g/cm^3 (Fig. 3).

Authors [20] made experimental tests and found that oat husk may contain 24.7–37.4% of cellulose, 31–38.4% of hemicellulose, 2.3–9.8% of lignin, 1.6–5.8% of protein and 2.4–9.3% of ash. Other authors [21,22] report the following chemical composition of barley husk: 21–39% cellulose, 12–46% hemicellulose, 12–22% lignin, 4–10% protein, 8–11% starch, and 3–4% fat.

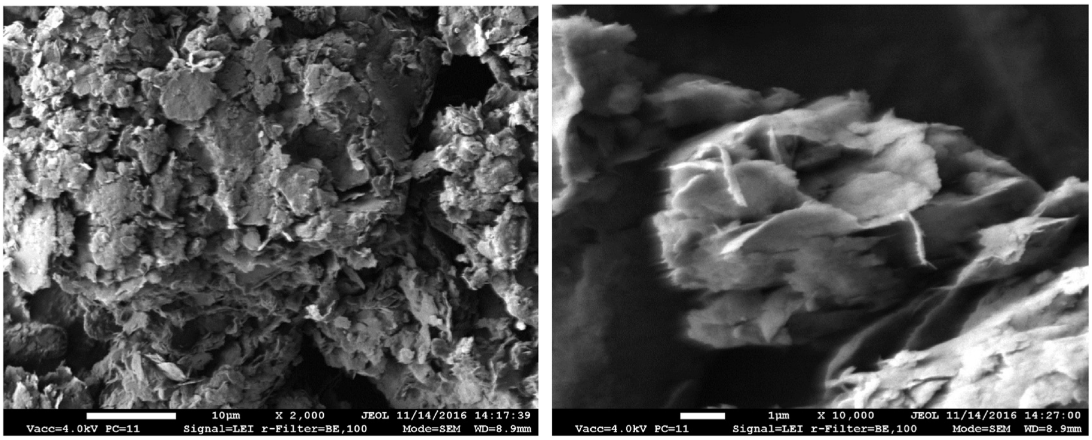
The elemental analysis of oat husk and barley husk and middlings mixture revealed that pH of oat husk is 6.1, dry

Table 2 – Chemical composition of the clay.

Raw materials	Chemical composition of the clay							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3
Clay	63.56	19.53	6.55	1.38	2.68	0.18	5.56	0.56

Table 3 – Particle size distribution in the clay.

Raw materials	>0.5 mm wt.%	0.5–0.063 mm wt.%	0.063–0.01 mm wt.%	>0.01 mm wt.%
Clay	0.2	1.8	22.4	75.8



a) b)

Fig. 2 – Microstructure of the clay.

Fig. 3 – Oat husk (OH) and barley husk and middlings (BHM).

matter content is 86.5%, and organic matter content on a dry basis is 94.2%. The pH of barley husk and middlings mixture is 6.6, dry matter content is 88.4%, and organic matter content on a dry basis is 96.7%. These by-products have a high content of dry matter, high C/N ratio and low concentration of heavy metals (Table 4).

Microstructure analysis of oat husk showed that the husk has a sufficiently thick and even external layer with a clean surface and uniform structure. The husk structure is quite different from the inside: it is porous with visible connecting pores of different size and form (Fig. 4a).

The external surface of barley husk and middlings mixture is dense and even, with visible traces of flour. The flour particles are of two types. One type is solid, round and dense particles with even surface; the other type is randomly distributed porous particles of various sizes (Fig. 4b).

TG–DTA results of both additives are very similar. The first 5% decrease in mass occurred between 20 °C and 150 °C temperature due to the evaporation of physical water. The second mass loss (about 75–83%) was observed at 200–500 °C temperature range and this loss may be largely due to the incineration of oat husk, barley husk and middlings (organic matter decomposition).

Physical and mechanical characteristics of ceramic bodies found through the tests are presented in Table 5.

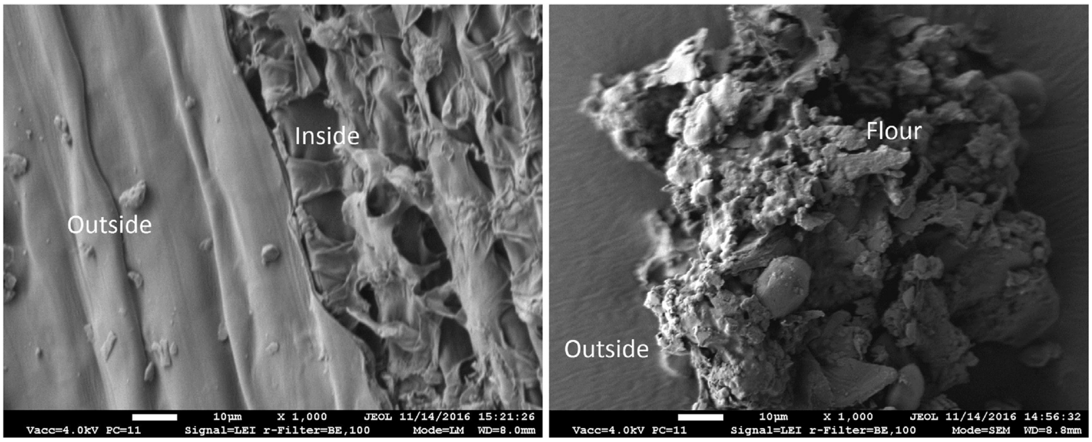
The results showed that agricultural solid waste reduces the drying shrinkage of the specimens and shrinkage after firing (Fig. 5). The effect of OH and BHM additives on the drying and firing shrinkage of the ceramic body is similar. The drying shrinkage diminishes because of the husk framework formed inside the moulded specimen. This framework prevents the moving of clay particles closer to each other during the drying. The husk stabilises the drying process irrespective of higher water demand in the forming phase. Organic additives incinerate during the firing (CO_2 emission) and additional structure of pores is formed. The liquid phase in the firing process is not sufficient to fill in that structure and to smooth the way for clay particles to get closer. For this reason specimens containing OH and BNM additive have lower firing shrinkage.

The additional structure of pores and insufficient liquid phase have an effect on the physical and mechanical characteristics of ceramic bodies. It was proved by further tests.

The ceramic mass fired at CS 900–1000 °C temperature had the density of 1.8–2.2 g/cm^3 and compressive strength of 25–29 MPa. Agricultural solid waste is a combustible additive. Pores of various sizes are formed as a result of additive combustion and gas (carbon dioxide) released during the firing

Table 4 – Elemental composition of cereal grain by-products.

Test parameter	Test results	
	Oat husk (OH)	Barley husk and middlings (BHM)
pH	6.1	6.6
Dry matter %	86.5	88.4
In dry substance		
Organic matter, %	94.2	96.7
Total nitrogen (N), %	1.80	1.92
Total phosphorus (P), %	0.30	0.37
Total potassium (K), %	0.86	0.91
Cadmium (Cd), mg/kg	0.028	0.018
Led (Pb), mg/kg	0.65	0.44
Chrome (Cr), mg/kg	3.7	3.3
Nikkel (Ni), mg/kg	2.2	1.9
Copper (Cu), mg/kg	4.02	3.84
Zinc (Zn), mg/kg	54.0	45.7
Organic carbon (C), %	48.5	44.9
C/N ratio	26.9	23.4
In natural substance		
Total nitrogen (N), %	1.57	1.65
Total phosphorus (P), %	0.24	0.26
Total potassium (K), %	0.71	0.78



a) b)

Fig. 4 – Microstructure of oat husk (OH) (a) and barley husk and middlings (BHM) (b).

process; subsequently the density of ceramic bodies increased and the compressive strength reduced.

The density of ceramic bodies containing 5% OH or BHM additive and fired at different temperatures dropped in average to 1.4–1.8 g/cm^3. 5% of OH additive reduced the compressive strength of the ceramic body to 5.3–7.5 MPa and 5% of BHM additive reduced the compressive strength to 7.8–9.5 MPa.

Actually, the compressive strengths of ceramic bodies containing 20% OH or HBM additive are rather low and differ depending of the additive type. Presumably, it is caused by the changes in macro and microstructures of the specimens during the firing. OH additive consists of coarse particles (Fig. 3); therefore, big pores and voids may occur after the firing and they can have a negative effect on the compressive strength.

Although standard EN 771-1 "Specification for masonry units – Part 1: Clay masonry units" does not specify the minimum compressive strength of clay bricks, some national classification systems specify the lowest normalised compressive strength value of 7 MPa or 5 MPa [5]. The tests results showed that clay bricks containing 5% of OH or BHM additive fired at 1000 °C temperature would meet this requirement.

The content of water absorbed by ceramic items usually depends on the volume, dimensions and distribution of pores. In the case of OH or BHM additives, the suction rate and water absorption increases. Water absorption is an important property that correlates with the durability of clay bricks. In the majority of cases the durability of clay brick reduces with higher water absorption. An author [23] argues that the highest water absorption value may not exceed 26%, while other authors claim that 30% is the limit [24]. In our case, only the

Table 5 – Properties of ceramic body.

Properties	Ceramic body firing temperature 900 °C/1000 °C						
	CS	OH5	OH10	OH20	HBM5	HBM10	HBM20
Density, g/cm^3	1.8 ± 0.003/2.2 ± 0.002	1.5 ± 0.003/1.8 ± 0.004	1.3 ± 0.004/1.6 ± 0.003	0.9 ± 0.003/1.3 ± 0.002	1.4 ± 0.003/1.7 ± 0.002	1.3 ± 0.003/1.6 ± 0.002	1.0 ± 0.002/1.3 ± 0.002
Compressive strength, MPa	25.0 ± 0.9/29.0 ± 1.0	5.3 ± 0.5/7.5 ± 0.4	3.3 ± 0.8/4.0 ± 0.5	0.8 ± 0.2/1.0 ± 0.4	7.8 ± 0.7/9.5 ± 0.6	4.6 ± 0.5/5.0 ± 0.4	1.9 ± 0.6/2.5 ± 0.3
Water absorption, %	14.5 ± 1.1/7.3 ± 1.4	22.0 ± 1.5/14.0 ± 1.1	25.0 ± 1.6/20.1 ± 1.3	42.6 ± 1.9/35.6 ± 1.7	16.7 ± 1.6/13.7 ± 1.2	28.0 ± 1.5/23.2 ± 1.2	49.2 ± 2.1/38.1 ± 1.8
Initial rate of water absorption, kg/(m^2 min)	1.0 ± 0.1/0.6 ± 0.12	1.7 ± 0.13/1.1 ± 0.12	2.9 ± 0.15/2.1 ± 0.13	4.5 ± 0.18/3.2 ± 0.16	1.7 ± 0.12/1.0 ± 0.14	3.3 ± 0.17/2.4 ± 0.13	4.8 ± 0.16/3.4 ± 0.14
Effective porosity, %	21 ± 1.8/15 ± 2.1	32.3 ± 2.1/25.1 ± 2.3	37.6 ± 2.3/29.6 ± 2.1	47 ± 2.8/42.4 ± 2.3	36.6 ± 1.8/28.1 ± 2.1	39.8 ± 2.4/35.1 ± 2.0	51.3 ± 2.6/45.5 ± 2.1
Total open porosity, %	27.2 ± 2.0/19.4 ± 1.7	41.7 ± 2.2/35.3 ± 1.8	47.2 ± 2.5/42.3 ± 2.0	62.4 ± 2.8/58.4 ± 1.9	43.8 ± 2.0/34.3 ± 1.6	49 ± 2.2/44 ± 2.1	66.7 ± 2.6/56 ± 2.2

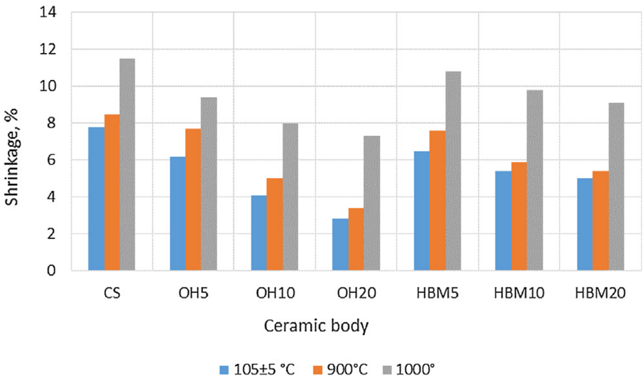


Fig. 5 – Shrinkage of ceramic body.

specimens with the highest OH and BHM additive content of 20% had water absorption value higher than 30%.

The initial rate of water absorption (suction rate) indicates the presence of interconnected pores, capillaries and voids in the ceramic body. The higher is the suction rate and water absorption, the higher is the effective and total open porosity of clay bodies. The same is confirmed by test results described below.

Organic components contained in the additives at the concentration of 94–96% (Table 3) decompose and incinerate during the firing, thus creating various pores and cracks, which increase the effective and total open porosity of the ceramic body. Higher content of OH or BHM additives increases the effective and total open porosity of ceramic bodies.

At higher firing temperature the effective and total open porosity as well as water absorption decreases [25–27]. These parameters indicate changes in the macro and microstructure during the firing. At higher firing temperature the clay particles get closer and the vitrification process becomes more intensive. Specimens fired at high temperature have less open voids and big pores for water ingress.

Fig. 6 shows the micro-structural analysis of samples fired at 1000 °C with different amounts of agricultural solid waste additives. The specimens with 0% content of solid waste of agricultural origin produced a dense matrix material with good surface characteristics (Fig. 6a, b). These results are in agreement with low water absorption, effective and total open porosity, high compressive strength and bulk density of the specimens (Table 4).

With higher content of the additive, the microstructure of the ceramic body becomes more porous. The pores are distributed rather evenly; however, the total pore volume and the amount of pores increases. The properties of fired clay bricks and their physical and mechanical properties are defined by their internal microscopic structure.

The microstructure of the ceramic body containing 5% of OH additive (Fig. 6c, d) is sufficiently dense and the surface is even. The connections between mineral particles are good, there are few elongated, evenly distributed pores, most of them are open-type. The effective porosity of such ceramic body reaches 25%, the density is 1.8 g/m^3, and the compressive strength is 7.5 MPa (Table 4). With the addition of 20% OH into the moulding compound the microstructure changes (Fig. 6e, f), the surface becomes very rough. Some bigger particles on the surface have limited connection with the matrix structure and negatively affect the strength properties of the clay brick. Ceramic bodies have a spongy structure, the total open porosity is as high as 50%, the density is 1.3 g/m^3, and the compressive strength is 1.0 MPa (Table 4).

The microstructure of ceramic bodies containing 5% of HBM additive is rather compact, the matrix is dense with the presence of elongated open pores (Fig. 6g, h). With the addition of 20% of HBM, the microstructure becomes uneven, the density reduces and the porosity increases. Nevertheless, the surface is more even compared to ceramic bodies containing 20% of OH additive, and the pores are more evenly distributed. Grains with weak connection to the matrix are visible on the matrix surface. The effective porosity of such a ceramic body reaches 56%, the density is 1.3 g/m^3, and the compressive strength is 2.5 MPa (Table 4).

The EDS spectrum of fired clay brick is presented in Table 6. EDS tests showed that O, Mg, Al, Si, K, Fe elements are present in all ceramic bodies; the control ceramic body CS and ceramic body BHM 5 also contain traces of Ti. OH or BHM additive added to the clay brick moulding mix reduce the content of Mg and Fe. Iron oxide is known to have the greatest effect on the colour of clay bricks [28,29]. Higher iron oxide content produces darker and more intensive colour of the clay brick. 5–20% OH or BHM additive in the mix makes the clay brick colour lighter.

4. Conclusions

The tested effect of agricultural solid waste (oat husk (OH) and barley husk and middlings (BHM)) on physical and mechanical properties, porosity and microstructure of the ceramic body showed that agricultural solid waste can be used as a combustible additive in the production of ceramic items (eco-friendly fired clay brick manufacturing).

The tests demonstrated that the addition of oat husk or barley husk and middlings have similar effects on physical and mechanical properties of eco-friendly fired clay brick because their element compositions and macro/microstructures are similar, they incinerate in the temperature of approximately 500 °C, forming a structure of various open pores in the ceramic body.

An additional structure of pores is formed as a result of incineration of organic additives (OH and HBM) during the firing process. The liquid phase of clay created by the firing process is not sufficient to fill in that structure and to smooth the way for clay particles to get closer. For this reason specimens containing OH and BNM additive have lower firing shrinkage, density, compressive strength, higher water absorption and porosity.

It is recommended to add 5% oats husk or barley husk and middlings and fire the bricks at 1000 °C temperature. Higher content of the additive reduces the compressive strength of fired clay brick.

The addition of 5% of oat husk into brick moulding compound and firing the brick at 1000 °C temperature

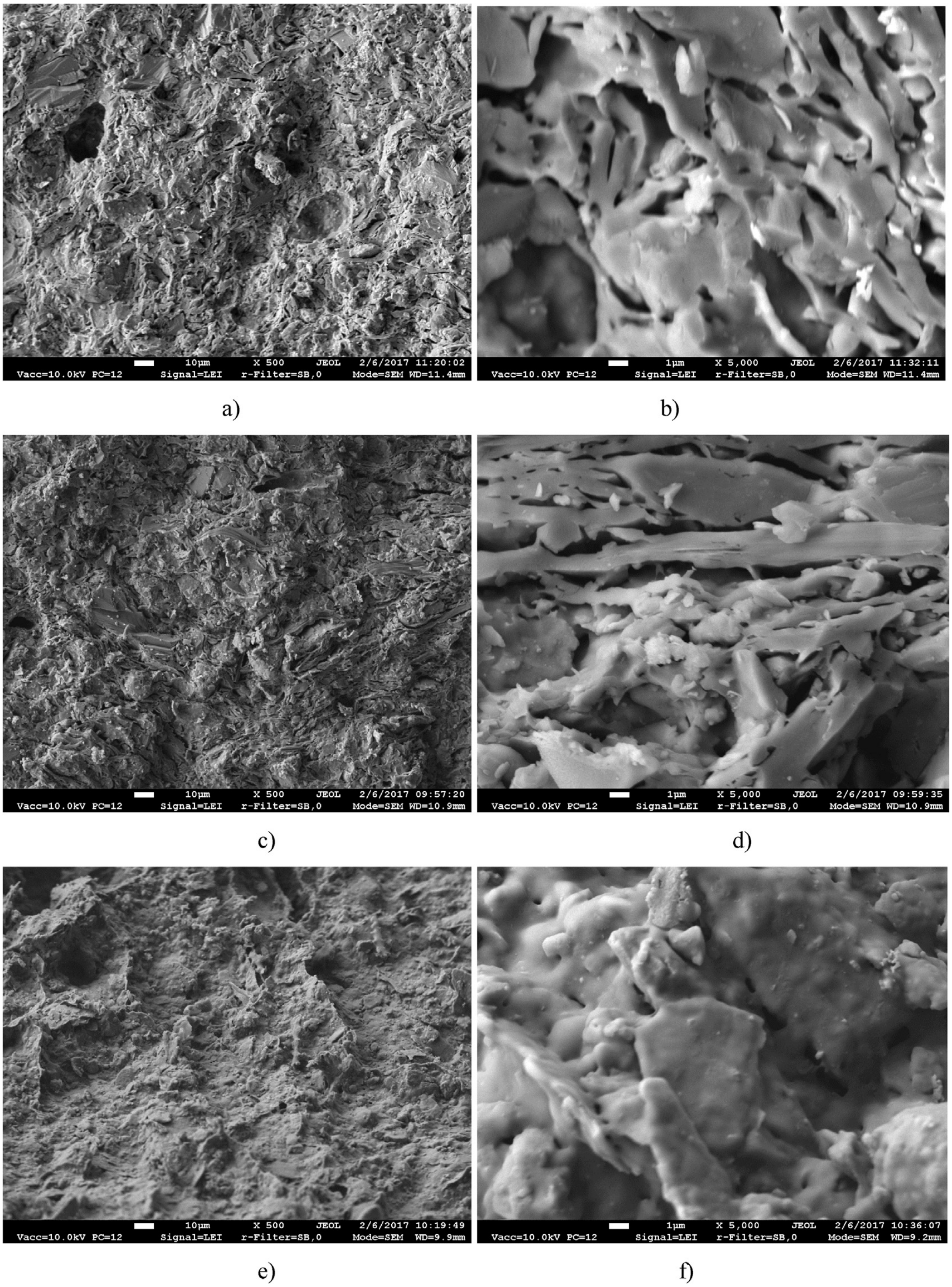
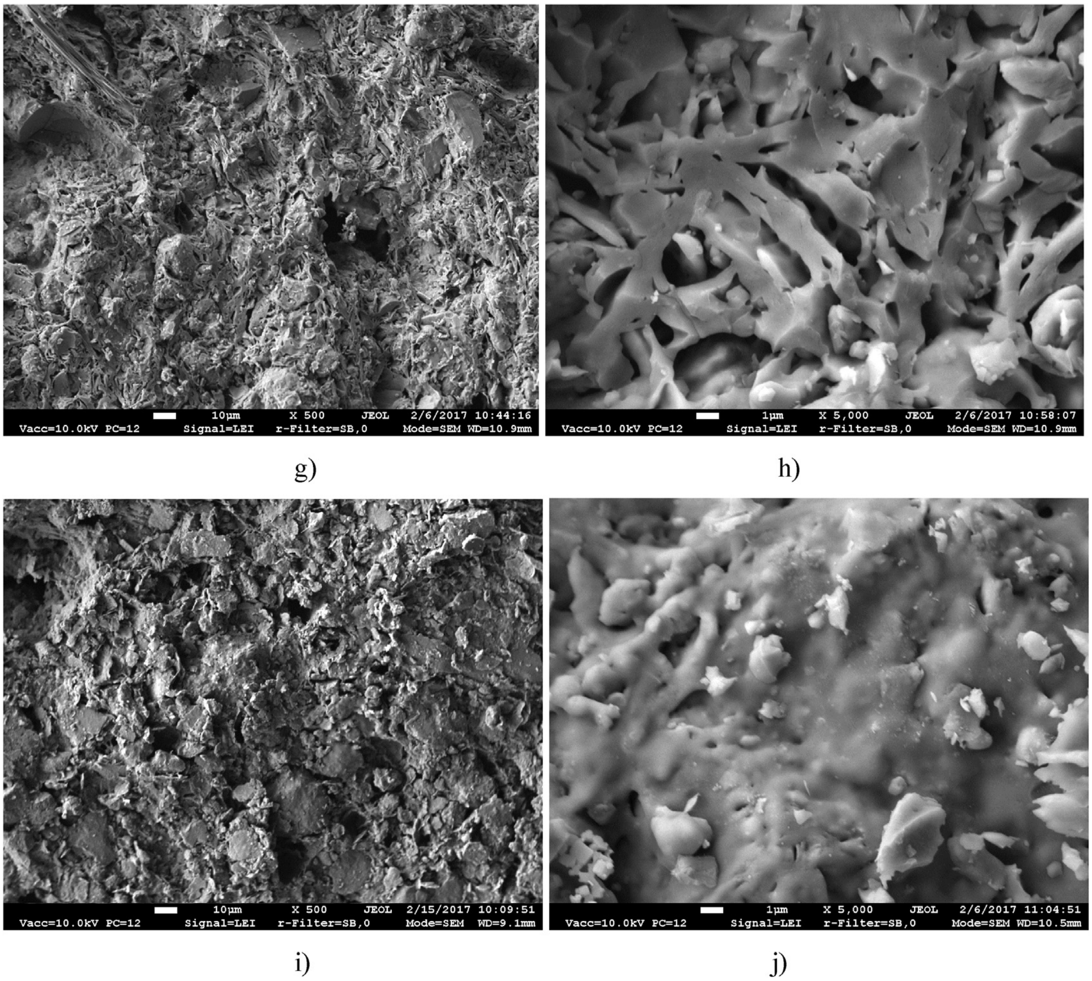


Fig. 6 – SEM images of ceramic bodies: ceramic body CS (a, b), ceramic body OH 5 (c, d), ceramic body OH 20 (e, f), ceramic body HBM 5 (g, h), ceramic body HBM 20 (i, j).

produces a fired clay brick with 1.7–1.8 g/cm^3 density, 9.4–10.8% total shrinkage, 7.5–9.5 MPa compressive strength, 13.7–14.0% water absorption and 34.3–35.3% total porosity.

The recycling of agricultural solid waste (oat hulls and barley mill by-product) in clay bricks shows positive results in terms of environment protection, waste management practices, and saving of raw materials.



g) h)

i) j)

Fig. 6. (Continued).

Table 6 – EDS analysis of fired clay brick.

	Analysis of all elements						
	Fired clay brick CS						
	O	Mg	Al	Si	K	Fe	Ti
Mean	46.44	2.97	10.46	25.02	4.59	9.83	0.68
Std. deviation	2.09	0.47	2.09	5.33	1.33	7.42	0.22
Max	48.48	3.29	12.83	28.66	5.88	18.34	0.85
Min	44.31	2.43	8.88	18.90	3.22	4.67	0.43
	Fired clay brick OH 5/fired clay brick OH 20						
Mean	49.52/47.06	2.01/1.84	12.58/13.01	26.88/28.06	5.46/5.96	3.55/4.07	–
Std. deviation	3.09/2.44	0.17/0.21	1.91/2.86	2.72/1.11	0.70/0.45	1.78/2.18	–
Max	54.93/48.79	2.14/1.99	13.95/15.03	29.74/28.84	6.27/6.28	5.60/5.61	–
Min	46.03/45.34	1.82/1.68	10.40/10.99	24.34/27.27	5.05/5.65	2.41/2.53	–
	Fired clay brick BHM 5/fired clay brick BHM 20						
Mean	42.46/45.98	2.15/2.83	12.74/10.60	30.66/26.61	6.83/5.30	4.37/8.68	0.78/–
Std. deviation	5.22/0.78	0.72/0.92	2.63/1.76	1.94/5.89	0.31/1.76	0.35/7.54	0.11/–
Max	16.14/46.61	2.66/3.78	14.60/12.44	32.04/31.37	7.05/6.48	4.61/17.37	0.86/–
Min	38.77/45.11	1.64/1.95	10.88/8.93	29.29/20.02	6.61/3.28	4.13/3.89	0.71/–

Author's contribution

All the authors namely, O. Kizinievič, V. Kizinievič, I. Pundiene and D. Molotokas developed the conception of the study and designed it strategically. Further, all the authors except D. Molotokas contributed equally towards data acquisition, analysis, and interpretation. These three authors drafted the manuscript and revised it critically for important intellectual content.

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