Journal of ENDEMISM: biodiverisity & environment
Vol 3, №1 2025

OPTIMISING THE IMPACT OF ALMOND SHELL POWDER ON THE PROPERTIES OF EFFECTIVE CERAMIC MATERIALS

S.E. Huseynova
Azerbaijan University of Architecture and Construction

Abstract: This article explores the effects of almond shell powder (ASP) as a modifier that induces porosity in ceramic brick materials. In this study, ASP was added to a mixture of clay and brick waste in four different ratios: 10% (N1), 15% (N2), 20% (N3), and 30% (N4). The ceramic brick samples were fired at 850°C, 950°C, and 1050°C for 2 hours, after which their physical and mechanical properties were analysed experimentally. The results indicated that as the ASP content increased, porosity also increased, leading to a decrease in density values. The compressive strength of the samples varied, with a maximum of 25 MPa and a minimum of 5.2 MPa. Additionally, the thermal conductivity ranged from 0.46 to 0.17 W/(m·K). According to the research findings, the samples N1 and N2, which contained 10% and 15% ASP and were fired at 850°C, met the requirements of relevant standards (ASTM C 62-13 (2013) and TS EN 771-1).

Keywords: cyanobacteria, Spirulina, Cladophora, antioxidants, anticancer properties.

***Corresponding Author:** sureyyahuseynova@gmail.com

Received: 15 December 2024; Accepted: 28 February 2025; Published: 30 March 2025

DOI:10,54414/XNWF9408

Introduction:

The increasing demand for ceramic bricks is driven by their lightweight nature and superior thermal insulation properties compared to porous concrete blocks. Since both a porous structure and high mechanical strength are required, research on the development of innovative ceramic materials has focused on utilizing renewable waste as a modifier. In general, the modifiers used in the ceramic brick industry are classified into two main groups: powders derived from natural minerals and powders obtained from renewable sources, such as agricultural plant residues and industrial waste (Georgiev, 2018; Viruthagiri, 2013)

In this study, almond shell powder was used as a porosity-inducing modifier. As is well known, Azerbaijan, being one of the largest almond producers in the region, generates tons of almond shells as waste each year through its almond processing factories. It should be noted that almond shells constitute approximately 35–75% of the almond fruit, meaning that from an annual production of ~1.5 thousand tons of almonds, around 0.5–1.1 thousand tons of shells are discarded as waste.

In the brick industry, brick fragments separated as waste are traditionally used as a common diluent modifier (additive). In this study, the purpose of using brick fragments was to achieve the required mechanical strength in the samples (Eroğlu, 2017; Demir, 2003).

Therefore, one of the alternative approaches to waste valorization is the incorporation of renewable waste materials into the production of construction materials.

Materials and Methods:

Samples were prepared from clay and brick fragments, ground to a fine powder, and mixed with almond shell powder at ratios of 10% (N1), 15% (N2), 20% (N3), and 30% (N4). The mixture was blended in a planetary mill and shaped into cylindrical moulds of 24x50 mm size, then dried at 50°C for 48 hours and fired at 850°C, 950°C, and 1050°C for 2 hours.

Porosity and water absorption were determined by measuring the mass of the samples after drying, boiling in water, and saturating with water. Bulk density was calculated based on these measurements.

Compressive strength was evaluated by applying hydraulic pressure and measuring the maximum force. Thermal conductivity was tested using a "TA Instruments FOX 314 Thermal Conductivity Analyzer."

Results and discussions:

1. Raw Materials Used in the Research

Clay - In this study, the raw clay material was sourced from the Binə clay deposit, located in the territory of the settlement of the same name. The deposit consists of Upper Pliocene-aged clay rocks, exhibiting an open brown and blue colouration. The clay layer, with a thickness ranging from 19.1 to 19.7 meters, is covered by a soil-vegetation layer of 0.1–0.6 meters. Based on its mineralogical composition, the clay belongs to the illite group. The chemical composition of the clay is presented in Table 1.

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O $+K_2O$
Mass, %	54.82-57.84	13.62-14.44	5.59-5.67	6.57-8.33	1.97-2.02	0.63-1.26	3.89-5.12

Table 1. Chemical composition of the clay (%).

The physical properties of the clay are as follows: water retention capacity of 18.38–20.28%, shrinkage after drying of 6.30–7.10%, water absorption of 15.75–17.31%, and bulk density ranging from 1.81 to 1.87 g/cm³. The compressive strength of the samples derived from the clay is 27.7–35.5 MPa, while the flexural strength is 14.3–18 MPa. The presence of CaO in the raw clay material plays a crucial role in enhancing the mechanical strength of the material (Fətəliyev, 2000; Martırena, 2006).

Brick Fragments - Brick fragments were used as a modifying agent to reduce the plasticity and shrinkage that may occur in ceramic materials (Eroğlu, 2017).

Almond Shell Powder (ASP) - Observations using an electron microscope have shown that almond shells contain large pores with diameters of 300–500 µm and small pores with diameters of 40–60 µm. The elemental composition of almond shells consists of C (72.27%), O (22.88%), N (3.87%), and Si (0.87%). Their chemical components include cellulose (38.48%), hemicellulose (28.82%), lignin (29.54%), alkali extract (14.03%), and benzyl alcohol extract (8.00%). The benzyl alcohol extracts from almond shells contain 17 types of organic compounds. Thermal stability analysis indicates that almond shells primarily reduce their volume at 260°C and 335°C. These characteristics suggest that almond shells are suitable for use in composite and porous materials (Li, 2018).

2. Experimental Section

2.1. Preparation of Samples

For the preparation of the ceramic mass, clay fragments and brick particles were first ground to a powder with a particle size of up to 1 mm. Almond shells were cleaned and dried at 50°C. The dried shells were then pulverized in an electric mill to a particle size of 400 µm. Almond shell powder was added to the mixture in proportions of 10% (N1), 15% (N2), 20% (N3), and 30% (N4). The mixture was subsequently homogenized in a ball mill under controlled moisture conditions.

Cylindrical samples with dimensions of 24 × 50 mm were prepared using moulds from the ceramic mass and dried at 50°C for 48 hours. The dried samples were then subjected to firing at three different temperatures (850°C, 950°C, and 1050°C) for 2 hours (Figure 1).

Fig. 1. Stages of sample preparation.

2.2. Conducted Tests

For each composition, two different samples were prepared, and the properties of the samples were studied using various testing methods. Determination of Porosity and Water Absorption - The mass of the samples dried at 105°C for 12 hours (W_1), the mass in water after boiling for 5 hours using the Archimedes method (W_2), and the mass of the water-saturated samples in the air (W_3) were determined. Porosity is calculated using the following formula:

$$\text{Porosity (\%)} = \frac{W_3 - W_1}{W_3 - W_2} \cdot 100 \quad (1)$$

$$\text{Water Absorption (\%)} = \frac{W_3 - W_1}{W_1} \cdot 100 \quad (2)$$

Determination of Bulk Density - The bulk density is determined using the results from the porosity test:

$$\text{Bulk Density} = \frac{W_1}{W_3 - W_2}, \quad (3)$$

Determination of Compressive Strength - After the samples were dried, they were subjected to compression under the load of a hydraulic press. The compressive strength is determined by the ratio of the maximum destructive load to the surface area of the sample:

$$\sigma = \frac{F_d}{S} \quad (4)$$

Determination of Thermal Conductivity - This test was conducted using the "TA Instruments FOX 314 Thermal Conductivity Analyzer (TCA)." The surface of the material is brought into contact with the sensor of the device, and the heat transfer from the material's surface to the interior is used to determine thermal conductivity.

3. Results of the Tests

The results of the tests conducted on the samples were compared with the standards set by ASTM C 62-13(2013) and TS-EN 771-1 [11] [12]. Significant results were obtained for the physical-mechanical properties depending on the mineralogical composition of the clay raw material, the amount of almond shell powder (ASP), and the firing temperature. No fine or large cracks were observed in the samples fired at 850°C, 950°C, and 1050°C. Normally, the shrinkage for fired clay bricks is considered to be 8%, while the results obtained in this study varied between 4% and 12%.

The density of the samples is influenced by several factors, particularly porosity and firing temperature. As shown in Figure 2, the density changes inversely with porosity. When the porosity was 20%, the density was 1.32 g/cm³, and when the porosity was 54%, the density decreased to 0.92 g/cm³. The highest porosity (54%) was observed in the samples fired at 1050°C with 30% ASP.

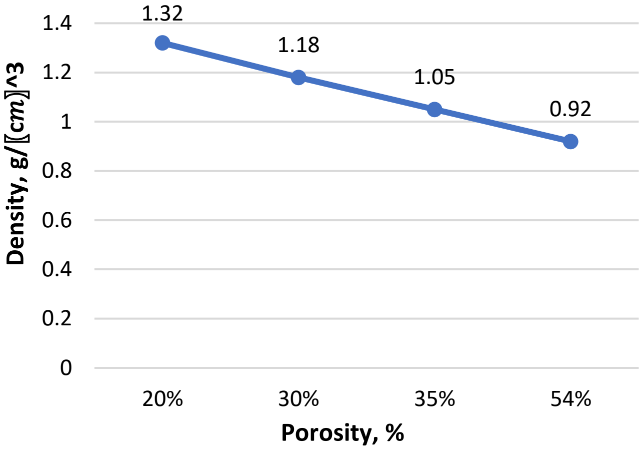

Fig. 2. Graph of the relationship between density and porosity.

One of the key factors determining the durability of clay bricks is water absorption. The water absorption values for almond shell powder (ASP) at 10%, 15%, 20%, and 30% content varied between 15.60% and 52.80% (Figure 3.). According to ASTM C62-13 (2013) standard, the water absorption should be 20.0%. Among the results obtained, only the N1 sample met the standard's requirement. As the amount of ASP increased, porosity also increased, leading to higher water absorption values.

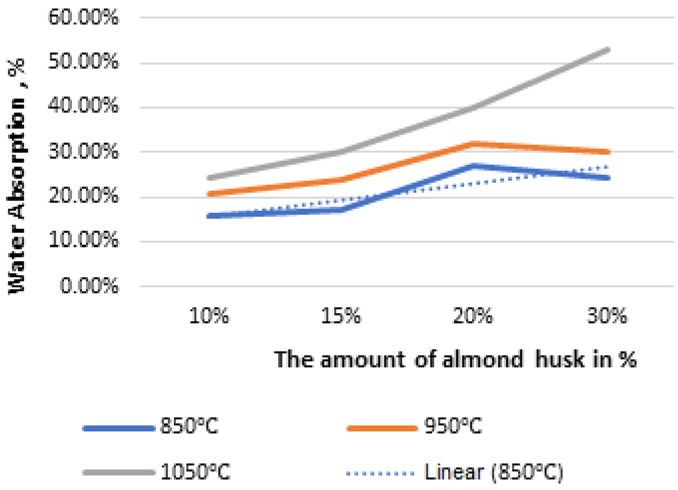

Fig. 3. Variation in water absorption of the samples depending on the firing temperature and the amount of almond shell powder (ASP), in percentage.

Another property that determines the quality of the material is the determination of the compressive strength limit (CSL) of the samples.

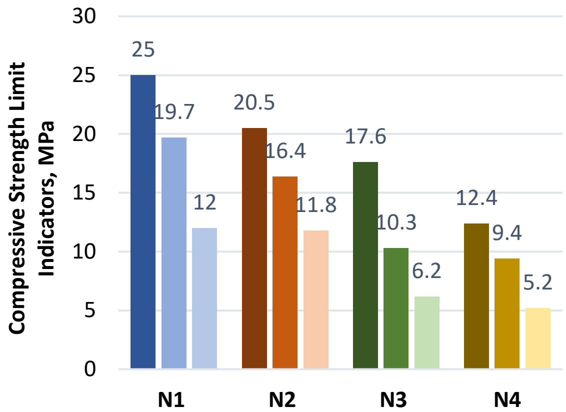

Fig. 4. Graph of the dependence of the compressive strength limits (CSL) of N1-N2-N3-N4 samples on the amount of almond shell powder (ASP).

As the amount of almond shell powder (ASP) increases, the porosity of the samples also increases, resulting in a decrease in the compressive strength limit. According to the TS-EN 771-1 standard, the compressive strength limit should be >7 MPa. The CSL values obtained from the N1 and N2 samples (25 MPa÷12 MPa; 20.5 MPa÷11.8 MPa) after firing at three different temperatures show high results, thus meeting the requirements of the standard.

Thermal conductivity is one of the most important criteria required for porous materials. According to the standard, the thermal conductivity of ceramic bricks should be below 0.60 W/(m·K). The thermal conductivity values obtained in the study ranged from 0.46 to 0.17 W/(m·K).

Conclusıon:

This research aimed to investigate the optimizing effect of almond shells, a renewable waste material, as a modifier on the properties of fired clay bricks. The behaviour of samples to physical and mechanical influences at varying raw material compositions was determined through experimental results, compared with international standards, and the results were found to be acceptable. Depending on the amount of almond shell powder (ASP), firing temperature, and porosity, the density of the samples ranged from 0.92 to 1.32 g/cm³. As porosity increased, the water absorption values also increased correspondingly. The compressive strength and thermal conductivity values for all samples were within acceptable limits. Based on the results, the physical and mechanical properties of the N1 and N2 samples met the requirements for porous ceramic materials. Therefore, almond shells can be considered a beneficial modifier both economically and practically.

References:

Georgiev, A., Yoleva, A., Djambazov, S., Dimitrov, D., Ivanova, V. (2018) Effect Of Expanded Vermıculıte And Expanded Perlıte As Pore Formıng Addıtıves On The Physıcal Propertıes And Thermal Conductıvıty Of Porous Clay Brıcks. Journal of chemical technology and metallurgy, 2: 275-280.

Viruthagiri, G., Nareshananda, S. N., Shanmugam, N. (2013) Analysis of Insulating Fire Bricks from Mixtures of Clays With Sawdust Addition, Indıan Journal of Applıed Research, 3(6): 469-473.

Eroğlu, M., Akyol, A.A. (2017) Antik Yapı Malzemesi Olarak Tuğla ve Kiremit, STD: 141-163

Demir, I., Orhan, M. (2003) Reuse of waste bricks in the production line, Building and Environment, 38(12): 1451-1455

Fətəliyev, S.A., İmanov, Ə.M., Bayramov, F.H. (2000) Azərbaycan Respublikasında tikinti materiallarının mineral xammal ehtiyatları, Bakı -2000.

Martırena, F., Day, R.L., Betancourt, D., Dıaz, Y. (2006) Improvement of Engineering

Properties of Fired Clay Bricks Through the Addition of Calcite, Proceedings of the 7th international masonry conference at: UK (Inglaterra), November, 2006.

Li, X., Liu, Y., Hao J., Wang W. (2018) Study of almond shell characteristics. Materials, 11(9), 1782