Mechanical Properties Effect of Clay Ceramics by Mixing with Activated Charcoal, Rice Husk Ash, and Sugarcane Leaf Ash

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Abstract. This experimental study aims to determine the effect of mixing rice husk ash, sugarcane leaf ash, and activated carbon on the mechanical properties of ceramics. Rice husks were obtained from the rice mill in Sawah Kulon Village, Pasawahan District, Purwakarta Regency. Sugarcane leaves were obtained from the Sugarcane Plantation, Purwadadi District, Subang Regency. While activated carbon were made of burning coconut shells. Rice husk ash, sugarcane leaf ash, and activated carbon powder were mixed with clay in a ratio of 25%, 50%, and 70% in volume percent. Each sample was burned at a temperature of 300 °C–350 °C within 3.5 h. Furthermore, the pressure test and bending test were carried out to determine the mechanical properties of the sample. The results shows that there is an effect of mixing the three materials on the hardness and flexibility of ceramics.

Keywords: Mechanical properties · clay ceramics · activated charcoal · rice husk ash · sugarcane leaf ash

1 Introduction

Ceramics are materials made by treating non-metallic minerals by various processes, including heat, to produce aesthetic or useful properties. By classification, ceramics are hard, wear-resistant, brittle, prone to overheating, flame retardant, electrical and thermal insulator, partially transparent, non-magnetic, chemically stable, and oxidation-resistant [1]. Generally, there will be exceptions, some ceramics are electrically and thermally quite conductive, while others are even superconducting [2, 3]. One type of ceramic that is often used for exhaust gas filters is porous ceramic [4].

The raw materials commonly used to make ceramics such as kaolin, clay, feldspar and quartz and bentonite [5]. Natural bentonite is a hydrated alumina silicate with the main element consisting of alkaline and alkaline earth cations of it compounds. Bentonite is a clay containing hydrated aluminum silicate compounds with alkaline earth main constituents and has high ion exchange and adsorption properties. So that bentonite minerals consist of several types of minerals, have a three-dimensional structure and have pores that can be filled by water molecules [6].

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Currently, the traditional ceramic industry is still become a destination place for tourism and economic transactions for the people of Indonesia. The sustainability of traditional ceramic industry is influenced by the number of ceramic sales. One indicator of the level of sales is the quality of ceramics. Ceramic quality can be improved through strengthening the mechanical properties of ceramic raw materials through coating [7] and the addition of organic materials such as activated charcoal and rice husk silica [2, 3, 6, 8].

The previous research shows there has been no study on the combination of the composition of activated charcoal powder, rice husk ash, and sugarcane leaf ash to improve the mechanical properties of ceramic raw materials. Therefore, this study aims to find the best composition of ceramic material consisting of a combination of rice husk ash, sugarcane leaf ash, activated charcoal powder, and clay. The results of this study are expected to be useful for traditional ceramic industry in improving the quality of ceramics through the mechanical properties of ceramic raw materials. In addition, this research is expected to formulate the composition of raw materials with a mixture of three organic materials that are effective in improving the quality of the mechanical properties of ceramic raw materials.

2 Method

2.1 Preparation of Rice Husk Ash, Sugarcane Leaf Ash, and Activated Charcoal Powder

Sample preparation was carried out by identifying ceramic raw materials and mixed materials i.e. rice husk ash, sugarcane leaf ash, and activated charcoal powder. Rice husks were obtained from the rice mill in Sawah Kulon Village, Purwakarta Regency, Indonesia. Rice husks are burned in an open space to represent the actual conditions. Rice husk ash is then collected in plastic bags to be taken to the laboratory. Sugarcane leaves were obtained from the Sugarcane Plantation, Purwadadi District, Subang Regency. For sugarcane leaf ash, the same treatment was carried out with the manufacture of husk ash. The sugarcane leaves are burned in an open space to get closer to the actual condition, then the leaf ashes are collected in plastic bags to be taken to the laboratory. The raw material for activated charcoal is coconut shells which are burned in an open space and then ground into powder. Furthermore, rice husk ash, sugarcane leaf ash, and activated charcoal powder were then filtered using a sieve with a mesh size of 10 or the equivalent of 2 mm per hole to obtain the same size of husk ash a maximum of 2 mm (Fig. 1).

2.2 Preparation of Clay Materials

Clay is a natural mineral that has 85% montmorillonite with the chemical formula (Al_2O_3 2 SiO_2 2 H_2O) and is used in traditional ceramic raw materials. This study used clay raw materials from Plered District, Tegal Waru District, Darangdan District, Sukatani District, Pasawahan District, and Babakan Cikao District. Based on an interview with one of the craftsmen, the clay was indeed taken from the six sub-districts, but 90% of the clay was taken from Citeko Village, Plered District due to a better quality.

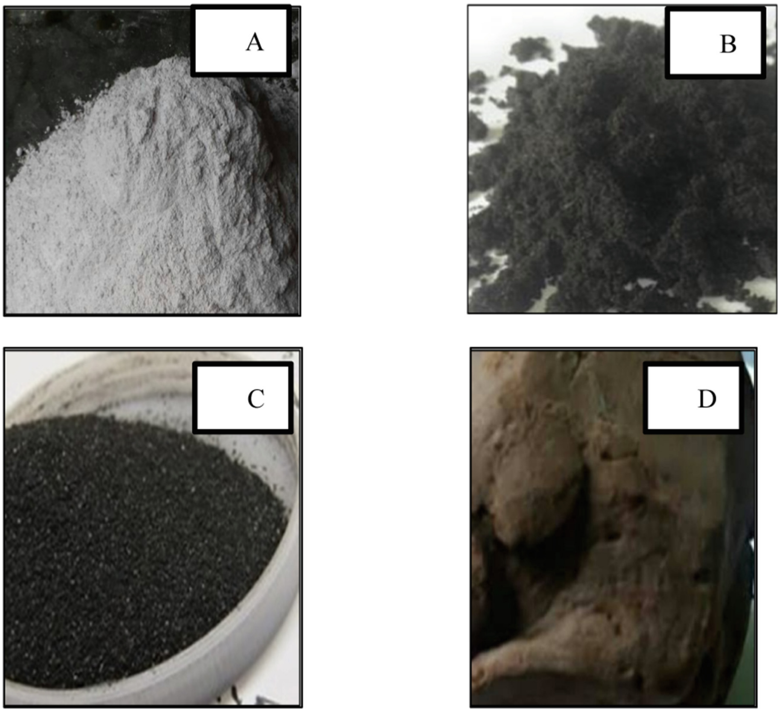

Fig. 1. Sample materials of (a) rice husk ash (RH), (b) sugarcane leaf ash (SC), (c) activated charcoal powder (AC), and (d) clays (Cy).

2.3 Sample Preparation and Analysis

The clays that has been taken from the craftsmen is then stored in an open room for 2–3 h to reduced water content of the clays. The purpose of this treatment is to make the clay easy to shape. Afterward, the clays were crushed and mixed to obtain uniform clay grain dimensions. This treatment was also applied to activated charcoal, rice husk ash, and sugarcane leaf ash. The four materials were mixed with the composition of rice husk ash, sugarcane leaf ash, activated carbon powder with clay, namely 25: 75; 50: 50; 75: 25 based on volume ratio. The whole mixture is printed on pellets. Furthermore, the pellet is heated at a temperature of 300 °C–350 °C for 3.5 h. Next, weigh the mass of the dry sample and measure the thickness of the pellet to obtain the sample volume. Then calculated dry specific gravity based on Eq. (1).

$$\rho = mV^{-1} \tag{1}$$

where ρ is dry density of ceramic sample (g.cm^{-3}), m is sample mass (g), and V is volume of sample (cm^{-3}).

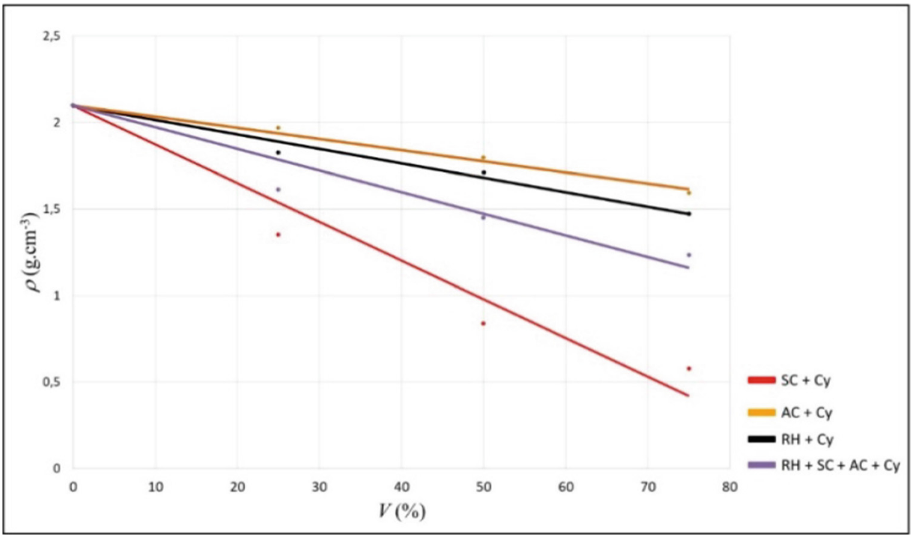

Fig. 2. Dry Ceramic Density Based on Volume Ratio.

2.4 Mechanical Test

Mechanical testing was conducted using a pressure test and a bending test. In pressure test, the sample was placed on the test equipment, then pressing it so that the ceramic part is damaged. The calculation of the compressive test is carried out using Eq. (2).

$$P = mA^{-2} \tag{2}$$

where P is the pressure strength (kg.cm^{-2}) and A is the sample surface area (cm^{-2}). The bending test was conducted by placing and installing the sample on the bending test equipment. After that, the machine is turned on and then turned off when the ceramic is broken or cracked. Bending strength is calculated using Eq. (3).

$$\sigma = 1.5plb^{-1}d^{-2} \tag{3}$$

where σ is the bending strenght (kg·cm^{-2}), p is the maximum weight (kg), l is the length of sampel (cm), b is the wide of sample (cm), and d is the thickness of sample (cm).

3 Result and Discussion

3.1 Dry Density of Ceramics

Dry density interprets the total mass content of the ceramic material. The higher density indicates that the material has more weight than the lower density. The results of the dry density calculation of ceramics are shown in Fig. 2.

To increase the density of ceramics, it can be done by adding mixed materials. Based on the Fig. 2 the highest average density of ceramics is ceramics with a mixture of

Table 1. Equation of Density of Ceramic Mixture.

Substances	Density Equation	R^2
Rice husk ash with clays	$\rho = -0{,}0083\ V + 2{,}097$	0,9795
Activated carbon powder with clays	$\rho = -0{,}0064\ V + 2{,}097$	*0,9897*
Sugarcane leaf ash with clays	$\rho = -0{,}0224\ V + 2{,}097$	*0,9564*
Rice husk ash, activated carbon, sugarcane leaf ash with clays	$\rho = -0{,}0125\ V + 2{,}097$	*0,9379*

activated charcoal (AC) and clay (Cy), while the lowest average density of ceramics is ceramics with a mixture of sugarcane leaf ash (SC), and clay (Cy). This condition is caused by the density of activated charcoal which is greater than the density of husk ash and sugarcane leaf ash. Mixing clay with activated charcoal will cause the average density of ceramics to increase. This increase in density also indicates that the ceramic material has a denser material content, so it is likely to have better resistance from accidental impact. Based on the Fig. 2, each mixture of ceramic materials has an equation that shows the relationship between the volume ratio and the density of ceramics as shown in Table 1.

Table 1 shows that a strong relationship between variables is shown by a mixture of activated charcoal powder with clay ($R^2 = 0.9897$). This means that the addition of activated charcoal increases the average density of ceramics compared to other mixtures.

3.2 Result of Ceramic Pressure Test

The pressure test is carried out by applying a pressure load to the ceramic. The test results show that there is an effect between the pressure tests on all ceramic mixture materials as shown in Fig. 3.

Based on the Fig. 3, ceramics with high pressure strength are found in a mixture of materials with a volume ratio of 25: 75, meaning that 75% clay and 25% a mixture of activated charcoal powder, rice husk ash, sugarcane leaf ash, or a mixture of all three. Based on graphic calculations, it is estimated that the ratio of 30: 70 has the best composition to produce the best quality. However, based on data, the highest compressive test results were found in a mixture of rice husk ash and clay with a volume ratio of 25: 75 ($P = 74.23$ kg·cm^{-2}). If a mixture of these materials is used as a ceramic raw material, it will produce ceramics with a better impact strength than other mixtures.

3.3 Bending Test of Ceramic

The bending test was carried out by applying a rotary load to the ceramic. The test results show that there is an effect between the bending test for all-ceramic mixture materials as shown in Fig. 4.

As in the pressure test, for the bending test results, the better composition from this test was at 25:75 based on the ratio of volume with the bending test value of 1438.2 kg·cm^{-2}. In other words, 25% composition of activated charcoal powder, rice

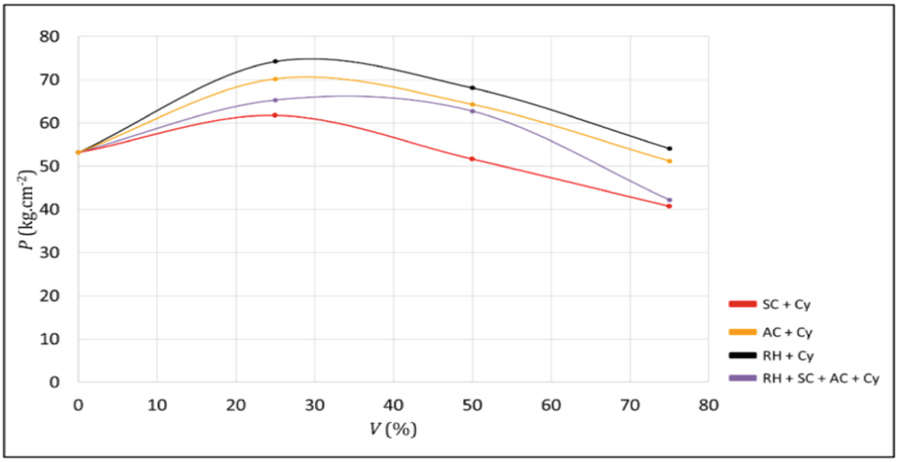

Fig. 3. Relationship between Volume Ratio with Pressure Strength.

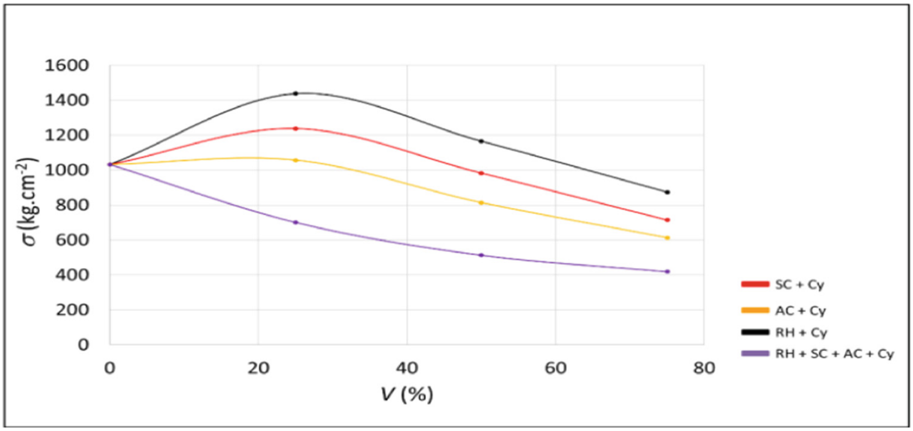

Fig. 4. Relationship between Volume Ratio with Ceramic Bending Test.

husk ash, sugarcane leaf ash, or a mixture of all three with 75% clay. Based on the composition of the four materials, the highest value of the bending test was calculated in the composition of rice husk ash with clay at a volume ratio of 25: 75. Meanwhile, based on the results of the graphic simulation, the bending test value was estimated in the composition of the material with a volume ratio between 25%–30%.

The two test results showed that the composition of rice husk ash with clay had the highest compressive and flexural test values when compared to the composition of other materials. This shows that ceramic raw materials with a mixture of rice husk ash can improve the mechanical properties of ceramics and the quality of ceramics so that they are impact-resistant and not easily damaged.

4 Conclusion

The quality of ceramics can be improved by adding a mixture of organic materials to the clay raw material. Based on the results of the pressure and bending tests, the best mixture of ceramic raw materials used a mixture of rice husk ash with clay with a composition of 25% rice husk ash. For further research, the microstructure of ceramics will be tested, so that it can be seen the role of rice husk ash in binding clay so that it can increase the value of mechanical properties testing.

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