Fabrication of porous clay ceramics material: substrate for slow-release fertilizer

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Abstract

The production of porous clay ceramics for different range of applications for agricultural and structural purposes are commonly use today. Generally, porous ceramics have better properties in terms of resistance, mechanical strength, low density, chemical and thermal stability. Though ceramics are porous in nature the study aims to fabricate a low-density clay ceramic with controllable pore sizes. Sacrificial fugitives' method was used in the fabrication, usually Styrofoam beads and sponges are the common material used as a pore-forming agent. When these materials were exposed to heat it releases fumes that contaminates air. Thus, using these materials can affects the environment and it risk workers health during the process. By utilizing sago as an alternative to styrofoam beads and sponges, eco-friendly porous clay ceramics were produced. For clay materials, Kauswagan and Surigao clay were tested. Various tests such as, clay quality and flexural tests were conducted to know what clay are more efficient to use. It was found out that kauswagan clay had a promising result in terms of clay quality and flexural strength with 0.03764 N/mm^2. To achieved porous clay ceramics, mixture of Kauswagan clay and sago are mixed together. The composition was 33% wt. amount of sago with respect to clay weight. Sago sizes also differ, three different sizes were used as pore-forming agent, powder, crushed, and pearl. Among the three pore-forming agents, pearl sago had a better result. The sample were furnaced at 950°C temperature and soaked for at least 2 hours. The results demonstrate a 62.153% porosity which is considered as highly porous ceramics. The average pore size is approximately 9.22 x 10^{-5} µm which is classified as micropore pore size according to the pore size classification. The density obtained is 2.9667 g/mL which is less dense compared to regular non-pore-forming agent ceramics. The results obtained in the study have given a promising result for further study to achieve better porous clay ceramics by adjusting some parameters in the study.

INTRODUCTION

Mindanao is endowed with rich mineral resources metallic and non-metallic resources. Its metallic deposits include lead, zinc, ore, iron, copper, chromite, magnetite and gold. While for its non-metallic minerals include marble, salt, sand, gravel, silica, limestone and clay. Mindanao has a total land area of 2,049,602 hectares and a highly mountainous region. Because of the geographical features of Mindanao, clay is one of the most abundant minerals that can be easily found. Kauswagan red clay is local clay material used in fabrication of ceramics. It is commonly used in pottery production at Lanao del Norte because of its multiple application in various industrial and agricultural applications.

Usually, clay is composed of mixture of fined-grained clay minerals of silica, alumina or magnesia or both and other minerals such as quartz, carbonate, and metal oxides. Clay is the main raw material to produce ceramics materials because of its special properties. These properties include: cation exchange capabilities, plastic behavior when wet, catalytic abilities, swelling behavior, and low permeability. One major factor that gives to clay minerals higher applications in multiple application because of its cation exchange capability which affects the mechanical and physical properties.

The study focused on the fabrication of low dense and reusable porous clay ceramics as a substrate for slow-release fertilizer. To obtain porous material sago will be utilized as a pore forming agent. Parameters such as pore-forming agent percentage and volume will be adjusted to achieve a low dense material.

METHODOLOGY

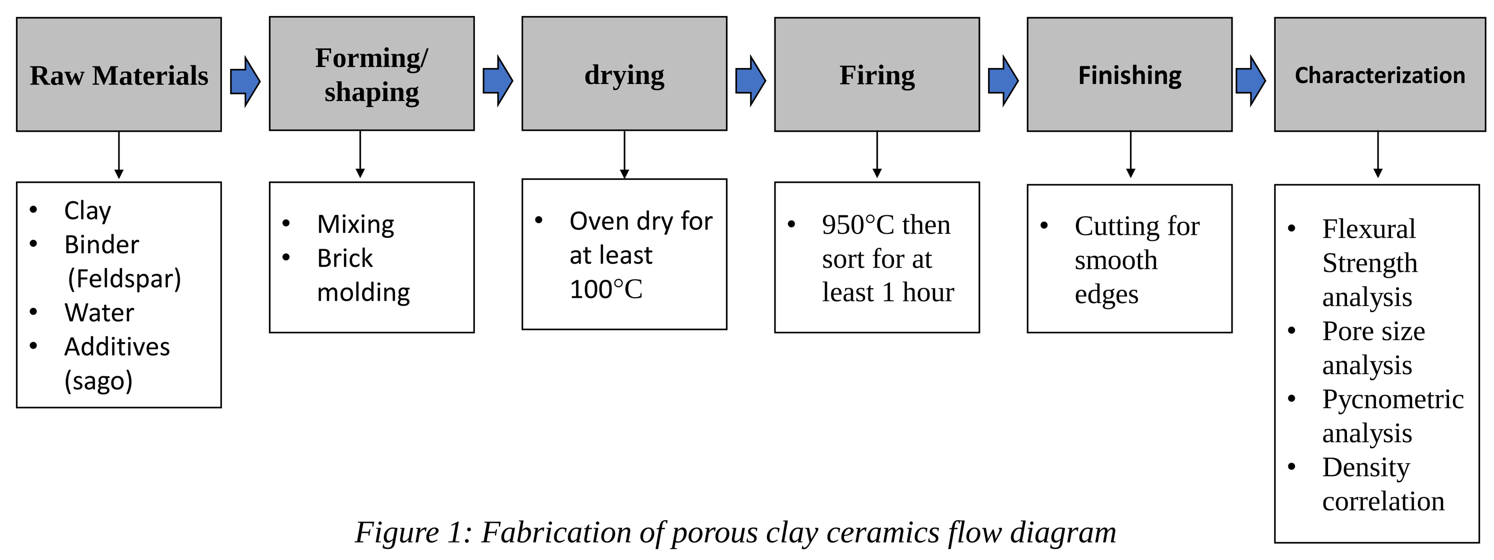
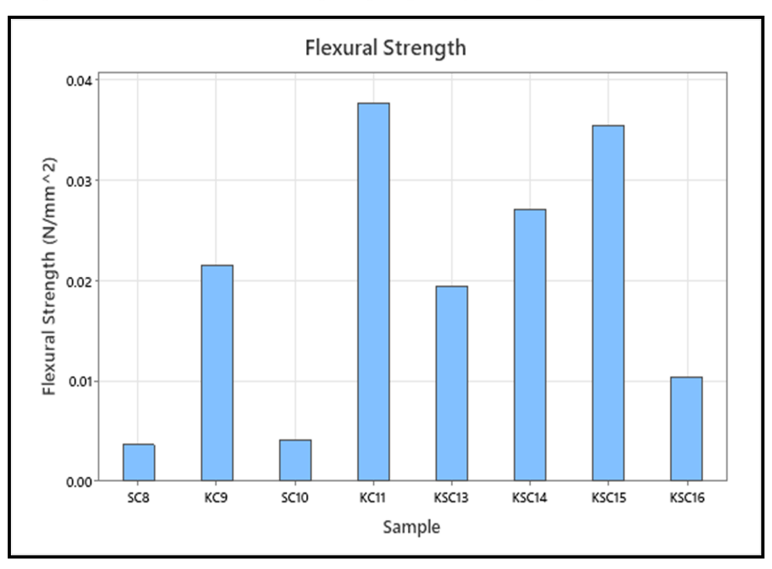


Figure 1: Fabrication of porous clay ceramics flow diagram

RESULT AND DISCUSSION

Flexural strength analysis

Figure 2: Flexural strength graph of non-porous ceramics

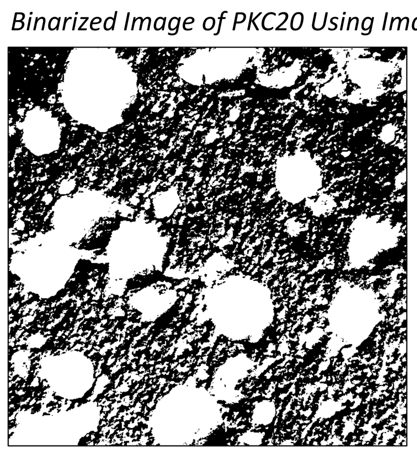


As observed in the graph, the results concluded that:

- Surigao clay (SC's) based samples is weaker compared to the kauswagan clay (KC's) based samples.
- Increasing the amount of feldspar appears to have increased the flexural strength.
- Mixture of Surigao and Kauswagan clay(KSC's) are good in terms of flexural strength but the problem is the texture of the product are sandy in nature.

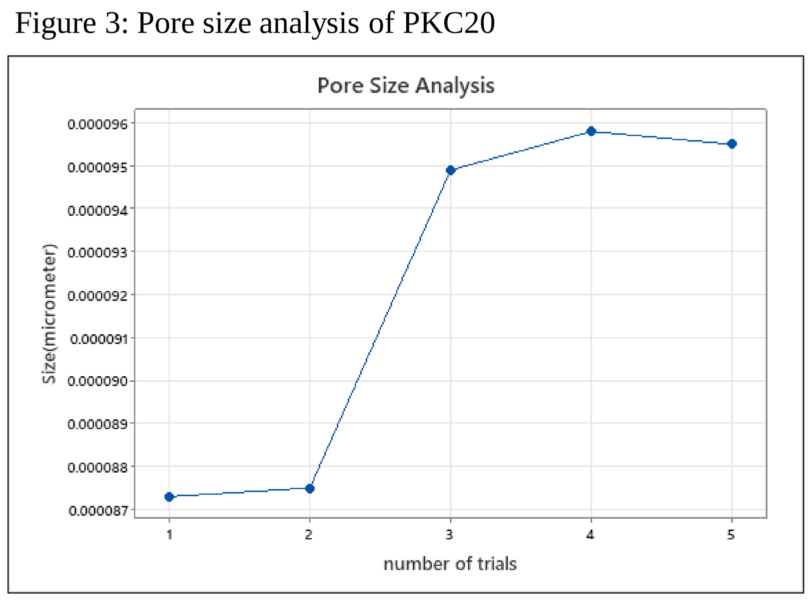
Pore size analysis

PKC20 with Ruler for Setting Scale



Binarized Image of PKC20 Using ImageJ

Figure 3: Pore size analysis of PKC20



Due to change in thresholding value pore count may change that affects the average size analysis.

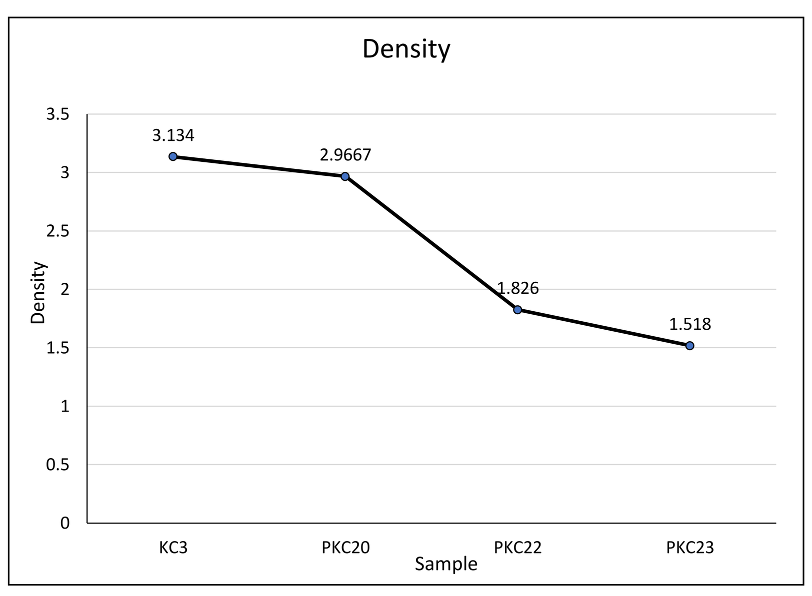
Thresholding value/trial
Trial 1 = 96
Trial 2 = 88
Trial 3 = 100
Trial 4 = 103
Trial 5 = 106

- The result shows that the average pore size is 9.22 x 10^{-5} µm as the result of five trials made for pore size analysis using ImageJ. According to pore size classification the pore size obtained is classified as Micropore size.

Pycnometric analysis

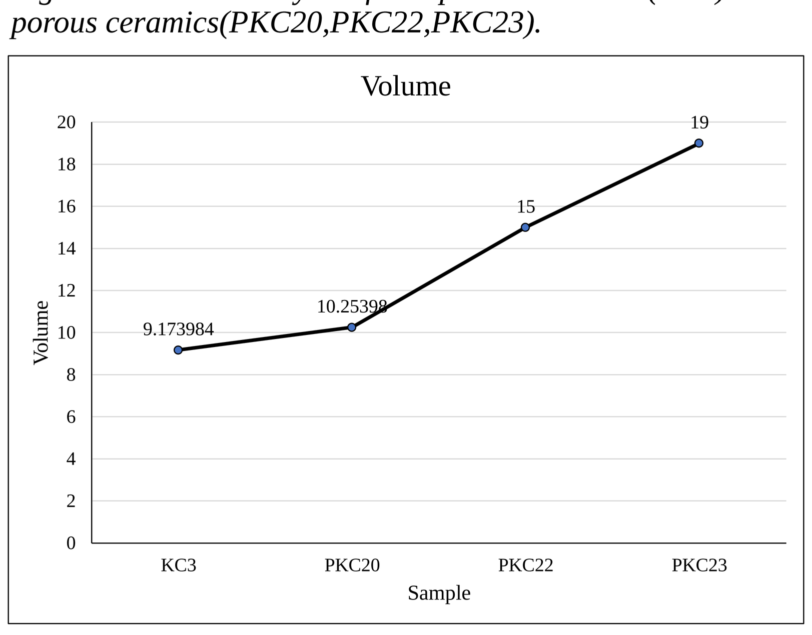
Note: PKC3 sample is the control ceramic with no pore-forming agent. While PKC20, PKC22, and PKC23 is the fabricated porous ceramics with pore-forming agent.

Figure 4: Density analysis of non-porous ceramics(KC3) and porous ceramics(PKC20,PKC22,PKC23)



- The result shows that no pore-forming agent sample KC3 obtained the highest density, while samples PKC20, PKC22, and PKC23 which are porous shows a decreasing density trend.

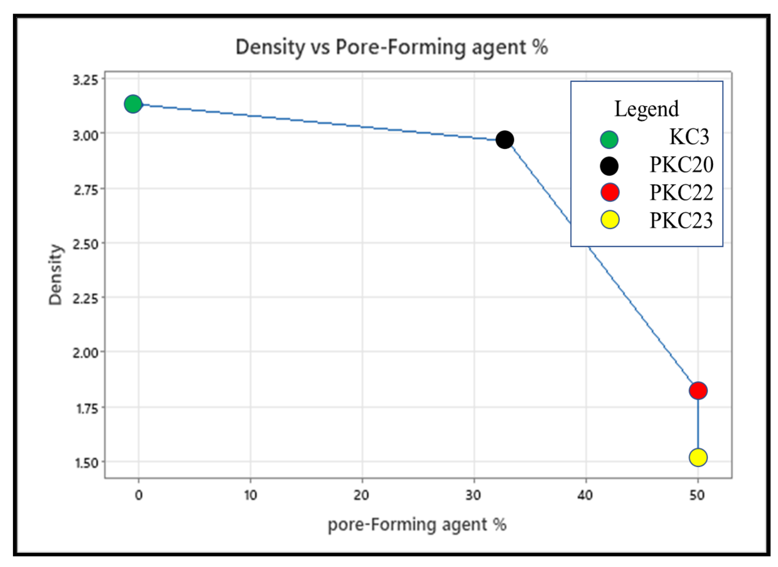
Figure 5: Volume analysis of non-porous ceramics(KC3) and porous ceramics(PKC20,PKC22,PKC23).



- As shown in the graph KC3 obtained the smallest volume and PKC23 obtained the highest volume. It is observed that the sample's shape and porosity differs to sample's change in volume.

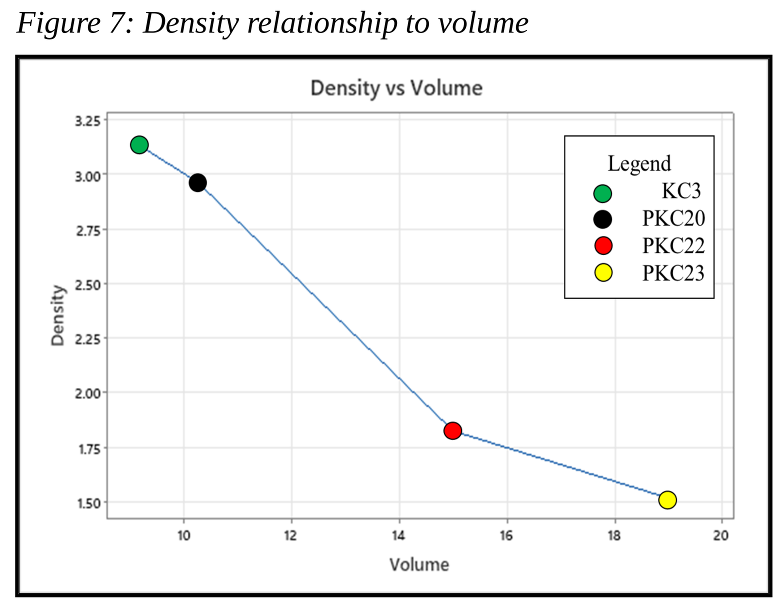
Density correlation

Figure 6: Density relationship to pore-forming agent percentage



- The result shows that density decreases as pore-forming agent percentage increases.
- Having more pore-forming agent percentage will create more open cell that makes ceramics low in density.
- Thus, density and pore-Forming agent percentage is inversely proportional to each other.

Figure 7: Density relationship to volume

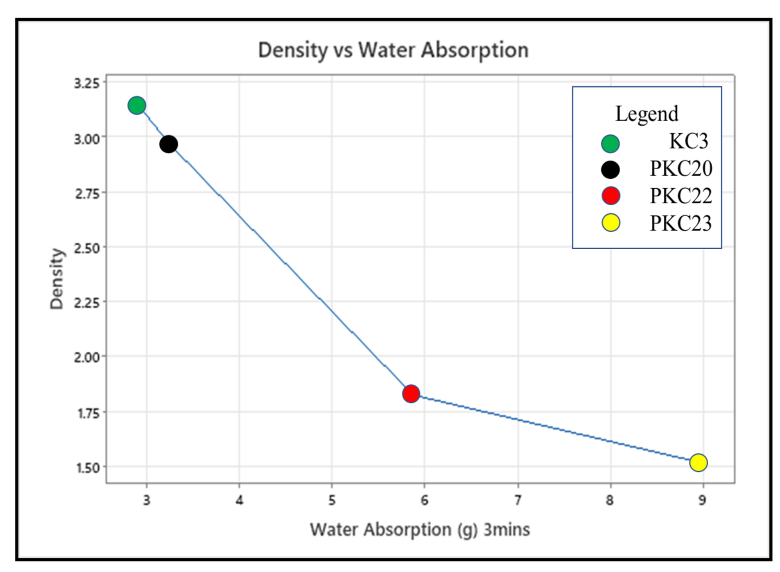


- As shown in the graph, when the volume of the fabricated ceramics increases, the density will decrease.
- Thus, density and volume are inversely proportional to each other.

Note:

Since porosity is not yet determined, volume can be disregarded in terms of change in density.

Figure 8: Density relationship to water absorption



- It was observed in the result that low density porous ceramics have high water absorption.
- Thus, density and water absorption is inversely proportional to each other.

Conclusion

The results shows that the fabricated porous clay ceramics using sago as pore-forming agent obtained an average pore size of 9.22 x 10^{-5} µm. Also the result shows a trend that density is inversely proportional to the parameters given, such as the volume, the percentage loading of pore-forming agent and the water absorption. For further study, to obtained less dense porous clay ceramics the parameters should be increased for a promising results.

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