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The Study of Mambong Clay Properties Improvement with Calcium Carbonate Addition

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Abstract. Mambong pottery is a unique heritage of Kelantan state with its own identity and features. However, the fabrication technique of this pottery can be improved to gain the product quality in terms of its properties. The additional of $CaCO_3$ as an additive opens the opportunities to improve the properties of this pottery. Four different compositions which are 0%, 5%, 10%, and 15% of $CaCO_3$ were used in 12 hours firing duration. The slip casting method was used in this research as the modern fabrication technique. The aim of this research is to study the Mambong clay properties improvement with different compositions of $CaCO_3$ addition.

1. Introduction

Ceramics referred to the art and science process of making useful products for man, made of inorganic and non-metallic materials by using heat and subsequent cooling method [1]. Generally, ceramic properties are exhibited extremely brittleness which is less ductility and highly susceptible to fracture. Ceramics can be classified into two main classes which are traditional ceramics and advanced ceramics.

Traditional ceramics are known as pottery, which is one of the oldest human technology using clay-based materials. Traditional ceramic is also based on silicate, silica, and other mineral oxides that can be found in nature. They are known as silicate ceramics. The raw materials used in the making of traditional ceramics are feldspar, silica, illite, kaolinite, and clay.

Basically, clay is an abundant raw material that can be found in the earth's crust. Clay is referred to any fine-grained, earthy, natural, argillaceous material which can be transformed into plastic when mixed with water and become hard when heated. The products made of clay also known as the pottery.

Pottery is a clay body form into any objects of the desired shape and heated to high temperatures in a kiln to sinter the clay body and become solid strengthen object [2]. The convenient firing temperature in the range of 900 – 1200 °C [3].

There are many types of pottery in Malaysia and the properties and characteristics are different from each other. For instance, in Perak, there are Labu Sayong as their traditional pottery; Terenang pottery in Pahang; and Pasu Sarawak in Sarawak.

Traditional pottery in Kelantan is known as Mambong pottery. This pottery was existed since hundreds of years ago with special identities especially shapes and patterns. This pottery was made from Mambong clay that was collected at Kampung Bahagia, near to Kampung Mambong, on the banks of the Galas River, Kuala Krai, Kelantan, Malaysia. The popular Mambong pottery are the undecorated earthenware, covered jars, and pots.

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Mambong clay originally greyish colour then turns into reddish after the firing process due to the high content of iron oxide in the clay and looks similar to terracotta pottery. Normal firing duration of this pottery in the range of 4 – 5 hours [4].

There are a few fabrication methods used in Mambong pottery. According to the previous researcher, Mambong pottery fabrication method consists of traditional and modern methods [5]. Traditional methods are including coil, pinch, and slab methods; while modern methods are including wheel throwing, jiggering and jollying, and also slip casting.

The slip casting method gives multiple productions of Mambong pottery compared to the old methods like hand-building, wheel-throwing, and jiggering and jollying techniques. One POP mold also can be used multiple times. Other than that, the slip casting method offers uniform shape and size by using the Plaster of Paris (POP) mold.

The Mambong pottery properties improvement needs renewal for its fabrication. One of the renewal technique is by adding some additives into the clay. $CaCO_3$ is suitable to use as an additive due to its abilities to support the clay properties improvement. $CaCO_3$ is one of the most abundant materials found in the earth's crust as the rock types like limestone and chalk. The specialty of $CaCO_3$ is to determine the refractoriness of clay. The clay with $CaCO_3$ addition needs less water to make them into a workable mass and shrink less on burning than other clays. Thus, the aim of this research is to study the effects of Mambong clay properties improvement with different compositions of $CaCO_3$ addition.

2. Materials and Methods

The aim of this experiment is to study the effects of $CaCO_3$ addition in Mambong clay for physical properties improvement. The materials used in this experiment are Mambong clay as the main material to produce the sample; then $CaCO_3$ as the additive material added into Mambong clay; and water as the mixing media to produce the slurry paste.

Table 1 shows the compositions used in this experiment to make the clay mixture for sample preparation. The base ratio is 55% of clay and $CaCO_3$; and 45% of water. The ratio of clay and $CaCO_3$ changed based on the amount of $CaCO_3$ used. Changes in sample compositions were converted in sample volume using:

$$M_{55-x}C_xW_{45} \quad (1)$$

Where,
M = Mambong Clay
C = $CaCO_3$
W = Water
x = $CaCO_3$ content

Table 1. Compositions that have been used in this experiment

Sample Code	Composition (%)		
	Mambong Clay (M)	$CaCO_3$ (C)	Water (W)
$M_{55}W_{45}$	55	0	45
$M_{50}C_5W_{45}$	50	5	45
$M_{45}C_{10}W_{45}$	45	10	45
$M_{40}C_{15}W_{45}$	40	15	45

A few steps were taken to complete the experimental works which are mold preparation, sample preparation, firing, testing, and analyzing.

2.1. Mold Preparation

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The Mambong clay mixture was prepared and shaped by using the slip casting method. The mold was set by the POP mixture. The POP powder were mixed with water by using the ratio of 2:1. The powder was mixed into water to form a slurry, then poured into the model template and left to set.

2.2. Clay Preparation
The raw Mambong clay was dried under the sunlight and grounded using a blender to form the clay powder. Then, the powder was sieved by using screening sieving below 425 µm to get a fine powder. By using slip casting method, the ratio of clay mixing is 55% of clay and $CaCO_3$ mixture; and 45% of water to form a slurry paste.

2.3. Slip Casting Process
After the complete mixing process, the slurry clay mixture was poured into the slip casting mold and left to set. Then, the clay green body was removed from the mold for drying process for 24 hours in room temperature.

2.4. Firing Process
The firing process must start with the fully drying process of samples in the oven with 80 °C for 24 hours to avoid thermal shock. The dried clay samples were placed in the furnace with 12 hours soaking time at the temperature of 900 °C. The heating rate was 5 °C per minute.

2.5. Testing and Analysis
The samples were tested and analyzed with various testing methods such as density, porosity, shrinkage, flexural strength, and Scanning Electron Microscope (SEM).

3. Results and Discussion

3.1. Density and Porosity
The density of the samples was measured using RADWAG Density Kit. The reading was taken for three times to get the accurate measurement. Table 2 shows the density and porosity percentage of each sample. The bulk density decreased by 9% as the $CaCO_3$ content increased from 1.68 g/cm^3 when no $CaCO_3$ added in sample $M_{55}W_{45}$ to 1.53 g/cm^3 at 15% in sample $M_{40}C_{15}W_{45}$.

The porosity were increased from 14.97% for sample $M_{55}W_{45}$ to 16.09% for sample $M_{40}C_{15}W_{45}$. The porosity increased due to the $CaCO_3$ turns into calcium oxide during the firing and the carbon dioxide released, which finally formed the pores in the samples. According to the previous study, a large increase in surface area on going from non-porous $CaCO_3$ to the oxide due to the pore formation [6]. Thus, when the $CaCO_3$ content increases, the pore sizes also increases. When the pore increased, the density became lower due to the air contained inside the sample increased. The lower density will produce lightweight pottery. Figure 1 shows the relationship between the density and percentage of porosity.

Table 2. Bulk density and apparent porosity of samples

Sample	Bulk Density (g/cm^3)	Apparent Porosity (%)
$M_{55}W_{45}$	1.68	14.97
$M_{50}C_5W_{45}$	1.62	15.03
$M_{45}C_{10}W_{45}$	1.59	15.68
$M_{40}C_{15}W_{45}$	1.53	16.09

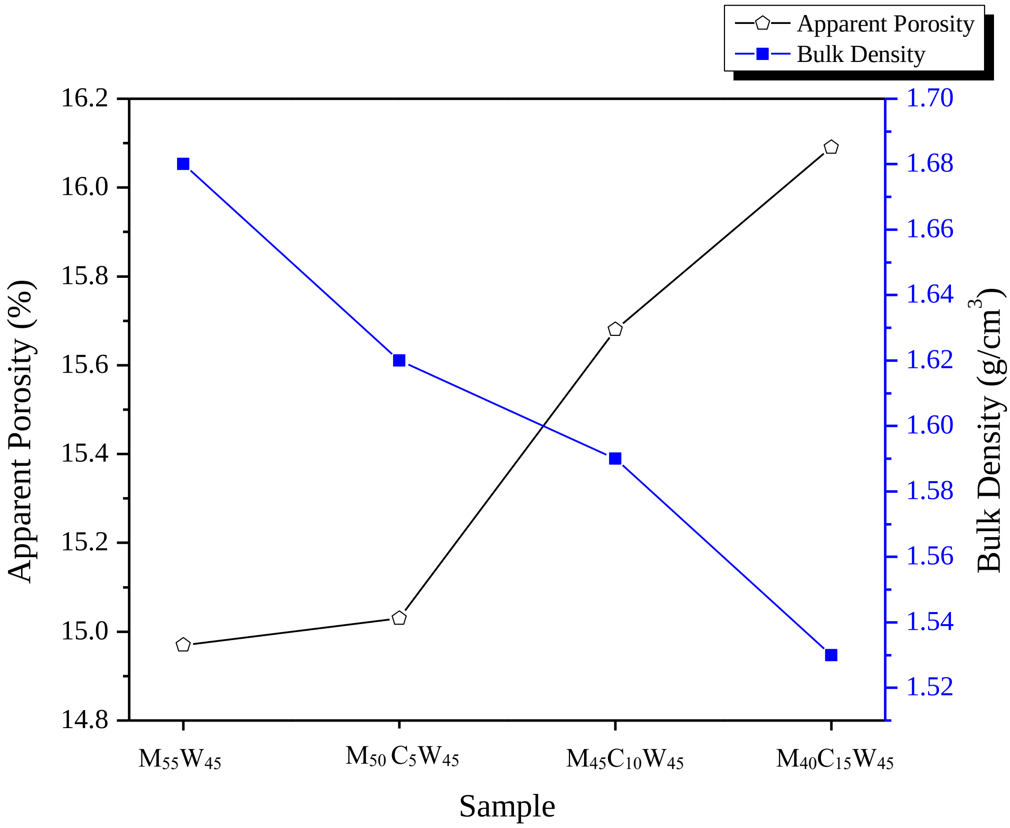

Figure 1. Relationship between bulk density and apparent porosity of samples

3.2. Shrinkage

The shrinkage rate of samples was measured using digital caliper before and after the firing process. The percentage of length reduction was calculated and shown in Table 3. The average shrinkage percentage of samples decreased as the $CaCO_3$ content increased, which 1.25% in sample $M_{55}W_{45}$ to 0.65% at 15% of $CaCO_3$ in sample $M_{40}C_{15}W_{45}$. This is due to the pores produced from the firing process and the shrinkage decreased when the pores larger. The lower the shrinkage percentage, the shape and size of the pottery remain the same.

Table 3. Average shrinkage percentage of samples

Sample	**Average Shrinkage (%)**
$M_{55}W_{45}$	1.25
$M_{50}C_5W_{45}$	0.95
$M_{45}C_{10}W_{45}$	0.82
$M_{40}C_{15}W_{45}$	0.65

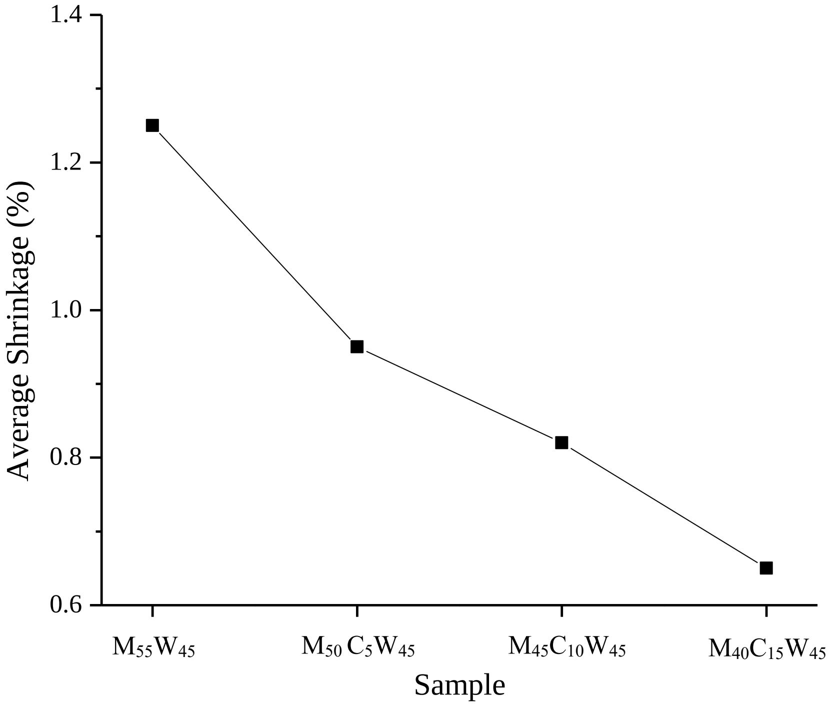

Figure 2. Average shrinkage percentage of samples

3.3. Flexural Strength

Table 4 shows the modulus of rupture (MOR) and bending strength were increased when the $CaCO_3$ content increased. MOR for $M_{55}W_{45}$ was 5394.811 N/mm^2 rose to 9599.263 N/mm^2 at 10% of $CaCO_3$ added in sample $M_{45}C_{10}W_{45}$. However, it dropped to 4449.880 N/mm^2 when 15% added in sample $M_{40}C_{15}W_{45}$.

Bending strength for $M_{55}W_{45}$ was 5.367 N/mm^2 rose to 8.344 N/mm^2 at 10% but dropped to 6.379 N/mm^2 at 15%. Due to the increased density, the porosity was decreased. The dropped reading of MOR and bending strength were related to the pore sizes and distribution. The highest strength of samples reached when 10% of $CaCO_3$ was added. This shows the optimum $CaCO_3$ content was at 10%. Then it dropped when higher content added. This might be happened because of too many pores based on the porosity percentage with 16.09%. Thus, it will lower the strength.

Table 4. MOR and bending strength of samples

Sample	**MOR (N/mm^2)**	**Bending Strength (N/mm^2)**
$M_{55}W_{45}$	5394.811	5.367
$M_{50}C_5W_{45}$	7651.837	6.090
$M_{45}C_{10}W_{45}$	9599.263	8.344
$M_{40}C_{15}W_{45}$	4449.880	6.379

3.4. SEM

Figure 3 shows the SEM analysis of Mambong clay after the firing process with 500x magnification. Figure 3(a) shows a microstructure with a large pore but rarely found in when no $CaCO_3$ added. The pores shown in the figures were circled. However, the pores in the figures became larger when the

$CaCO_3$ content increases. In figure 3(b), (c), and (d), the pores distribution became wide and larger due to the $CaCO_3$ content increases. This can be related to the density and porosity stated before. The density and porosity of the samples depended on the pore sizes and distributions. The larger the pores and well distributed, the higher the porosity percentage and the density will be decreased.

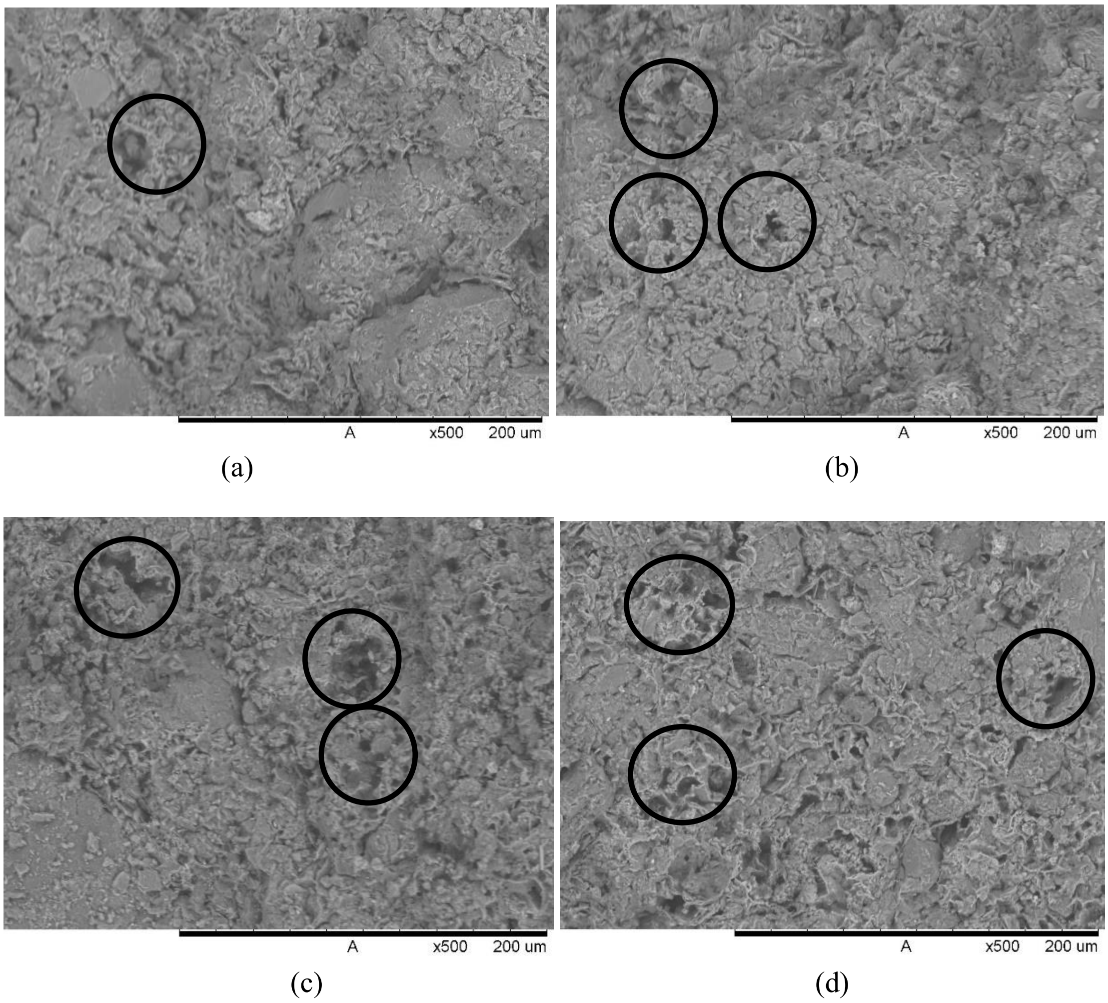

Figure 3. Microstructure of sample (a) $M_{55}W_{45}$; (b) $M_{50}C_5W_{45}$; (c) $M_{45}C_{10}W_{45}$; and (d) $M_{40}C_{15}W_{45}$

4. Conclusion

The additional of $CaCO_3$ as an additive opens the opportunities to improve the properties of Mambong clay. Four different compositions which are 0%, 5%, 10%, and 15% of $CaCO_3$ gave different results. The density is lower as the porosity percentage increases. This is due to the pore sizes and pore distribution shown in microstructures. The shrinkage percentage became lower due to the porosity increases. The lower density of the clay will produce the lightweight of pottery products. Then, lower shrinkage percentage will produce the products with the uniform shape and the sizes remain the same. However, in MOR and bending strength results, it shows that sample $M_{45}C_{10}W_{45}$ with 10% of $CaCO_3$ addition is the optimum $CaCO_3$ content with the highest strength. Thus, based on overall results, sample $M_{45}C_{10}W_{45}$ with 10% of $CaCO_3$ content is the best sample to improve the properties of the Mambong pottery.

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