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PRELIMINARY STUDY ON CHEMICAL AND PHYSICAL PROPERTIES OF BALL CLAY AND ITS SINTERED CERAMIC PIECES FROM KAMPUNG DENGIR, BESUT, TERENGGANU

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Abstract: Ball clays are fine-grained, high plastic sedimentary clay, and when fired will produce a light or near white colour. In this study, the chemical properties of ball clay from Kampung Dengir were characterized by using X-Ray Powder Diffraction (XRD) and Thermo Gravimetric Analysis (TGA) techniques. Ceramic piece was prepared by mixing of ball clay with water in a ratio of 2:1 for 2 hours and was aged for 24 hours before casting on the flat Plaster of Paris mold. The green body obtained was cut to form rectangular pieces and dried at 100°C before it undergoes thermal treatment at temperatures ranging from 800 to 1200°C for two hours with heating rate set at 5°C/min. Sintered ceramic piece was characterized by firing shrinkage, density, porosity and water absorption analysis. XRD analysis shows that the minerals present in ball clay were kaolinite, quartz and hematite. TGA analysis revealed the ball clay consists of 1.2% of water and 6.0% of organic materials, respectively. A good ceramic piece without cracks was obtained after casting give an indicator that this ball clay is suitable for making ceramic products. The properties of ceramic piece are highly influenced by sintering temperature. As the sintering temperature increased the amount of shrinkage and density was increased while porosity and water absorption decreased.

Keywords: Ball clay, ceramic, Kampung Dengir, Setiu Wetlands, sintering temperature

Introduction

Ceramic is a clay material that is shaped into the desired forms and then fired to produce desired properties. Ball clay is vital ingredient in ceramic manufacturing. Most of the ceramic products such as pottery, stoneware, sanitary ware and dinnerware consist of ball clay in their formulation (Baioumy *et al*., 2014). Ceramic body normally consists of three major components such as clay which is impart plasticity, feldspar serve as flux which provides the glassy phase during sintering (Matthew & Fatile, 2014) and silica which is used as filler and stabilizer (Kamseu *et al*., 2007; Baccour *et al*., 2009).

According to British Geological Survey (2011), ball clays are fine-grained, high plastic sedimentary clay, when fired will produce a light or near white colour. In Malaysia, ball clay is generally found in North Peninsular Malaysia such as in Perak which is famously known with the production of its traditional ceramic product known as *'labu sayong'* (Norhayati & Nurhana, 2013). Clays deposit in Sayong, Perak and Mukah in Sarawak contains kaolinite and quartz as dominant minerals with the presence of others elements (Edama *et al*., 2013; Seli *et al*., 2013). However, ball clay can also be found at the low ground in Terengganu. According to the Department of Mineral and Geosciences Malaysia, there are six major areas of potential ball clay in Terengganu, with approximately 151 million metric tons can be exploited as potential minerals sources including 4.7 million metric tons from Kg. Dengir, Besut, Terengganu (Ngah *et al*., 1994). Ball clay is particularly valued for their plasticity property and acts as a binding agent which gives strength to the ceramic green body beforefiring process. The differences in chemical compositions of clay minerals may affect the rheology properties of the ceramic slurry which plays an important role in slip casting process.

The main factors that influenced the quality of the ceramic products are the raw materials, fabrication methods, drying procedure, firing temperature and firing profile (Cultrone *et al*., 2005). However, the durability and strength of the ceramic body are related to their mineralogy and microstructure obtained via heat treatment (Livingston *et al*., 1998). The porosity of the clay also needs to be considered as it influenced its compressive strength, water absorption and permeability (Khalaf & DeVenny, 2002).

Sintering in the presence of liquid was recognized as a complicated process that is associated with remarkable shrinkage due to the evaluation of microstructure involved through the flow of viscous phase between the particles by capillary pores (Esposito *et al*., 2005). The glass phase flow of materials starts to shrink when it reached the transition temperature while the consolidation of structure occurs reducing the porosity of the materials (Norhayati & Nurhana, 2013). Firing shrinkage play an important role in the ceramic processing which is used to predict the size of the final ceramic product. Increasing the volume of water used during slip casting process may lead to decrease in the volume of clay which known as shrinkage (Soni *et al*., 2015). Temperature in the range of 1000ºC to 1600ºC is suitable in ball clay that can withstand chemical erosion that occurs in other materials subjected to acidic or caustic environment (Norhayati & Nurhana, 2013).

In this study, ball clay from Kg. Dengir was investigated for their suitability in producing ceramic products. Ceramic pieces were sintered at different temperatures (800-1200ºC) in order to study the effect of sintering temperature to physical properties of ceramic piece.

Materials and Methods

Clay sample was collected at E 102°29.51040' and N 05°45.41862' Kampung Dengir, Besut, Terengganu as shown in Figure 1.

Figure 1: Location of sampling area at Kg. Dengir, Besut, Terengganu

Clay was dried and grinded before sieving to 65 micron particle size. Clay was mixed with water at a ratio of 2:1 to form ceramic slurry and aged for 24 hours. Slurry was casted on flat Plaster of Paris mold before being cut into rectangular pieces. The pieces were dried in room temperature for 24 hours and then in oven at 100°C for 24 hours before sintered at 800-1200°C.

X-Ray Diffraction Miniflex 2 (Rigaku) and Thermogravimetric (TGA) were used to characterize clay samples. Firing shrinkage of sintered test piece was determined by measuring

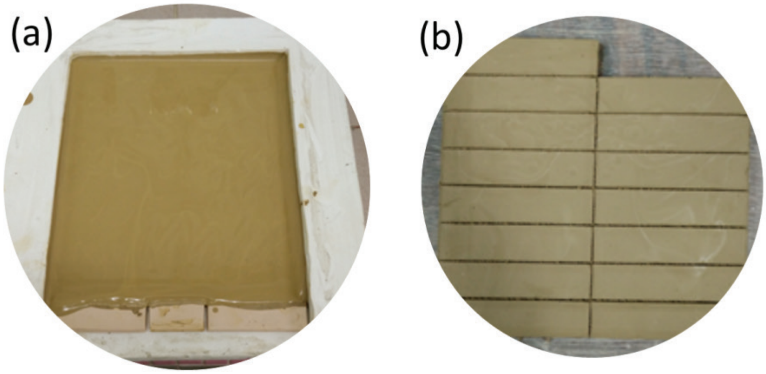

Figure 2: Ceramic pieces produced from ball clay without any cracks; (a) casting on Plaster of Paris mold and (b) cut into pieces for testing

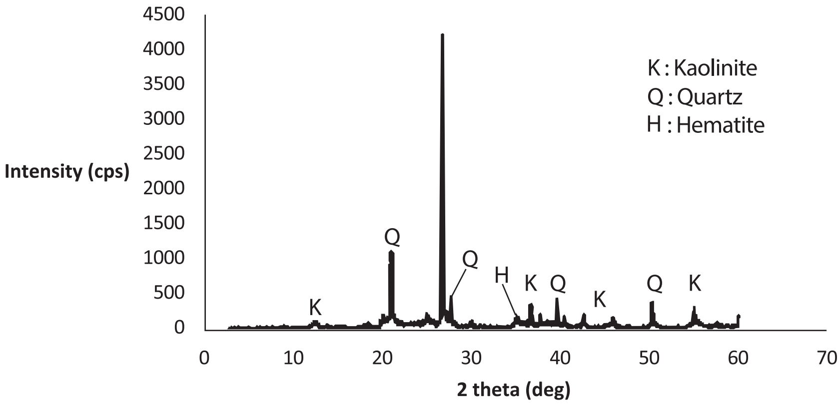

Figure 3: XRD pattern of mineral compositions in the ball clay

size of sample before and after sintering while density and porosity were determined using Archimedes method. Water absorption test was conducted by weighing the ceramic pieces before and after soaking in water for ten minute. The difference in weights of test pieces before and after soaking is used to calculate percent water absorption.

Results and Discussion

Ceramic Piece

Obtaining a good green body without presence of crack is one of the utmost important criteria in ceramic production. An acceptable quality of ceramic pieces without any cracks was produced using raw ball clay as shown in Figure 2. In common cases, if the clay is not suitable, the product will crack during unmold or drying process. It is a clear indicator that this clay is suitable to be used as raw materials for producing ceramic products.

XRD Analysis

The XRD analysis was used to investigate the presence of mineral within the ball clay. XRD pattern in Figure 3 shows three minerals present in the ball clay are kaolinite, quartz and hematite. These minerals are most commonly found in clay samples (Seli *et al*., 2013). Highly crystalline kaolinite area was displayed by narrow and sharp peaks (Rafaey *et al*., 2015). The presence of inorganic pigment such as iron oxide (hematite) may influence the colours of the final ceramic product (Bondioli *et al*., 1998).

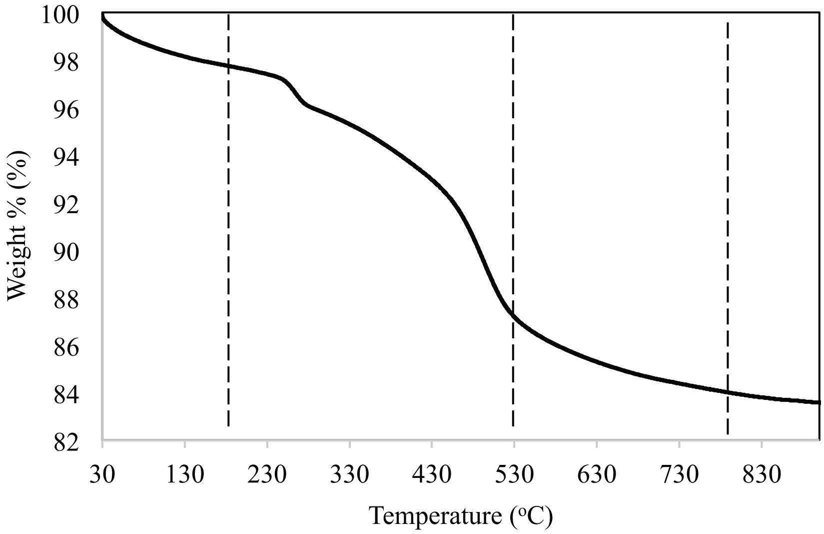

Figure 4: TGA spectrum of ball clay

TGA Analysis

TGA thermogram of the ball clay sample which undergoes heating in nitrogen atmosphere showed three degradation steps were shown in Figure 4. The first weight loss which is about 1.2% took place below 200ºC was related to the dehydration of physically adsorbed water on crystals surface and water molecules around metal cations in the silicate layer as mentioned by Xi *et al*. (2007) and Lenza *et al*. (2012). The degradation of organic substances occurred in two steps with the total weight loss of organic substances of around 6% in the range of 200 to 600 ºC.

Firing Shrinkage and Density

Firing shrinkage and density of ceramic pieces are essential to predict the size of the final product and the strength of ceramic pieces, respectively. It is clearly seen in Figure 5 that the firing shrinkage and density of ceramic piece were increased with increasing sintering temperature. The percentage of firing shrinkage was low at sintering temperature below 1000ºC which is less than 5%, however it increased drastically at the temperature of 1100 and

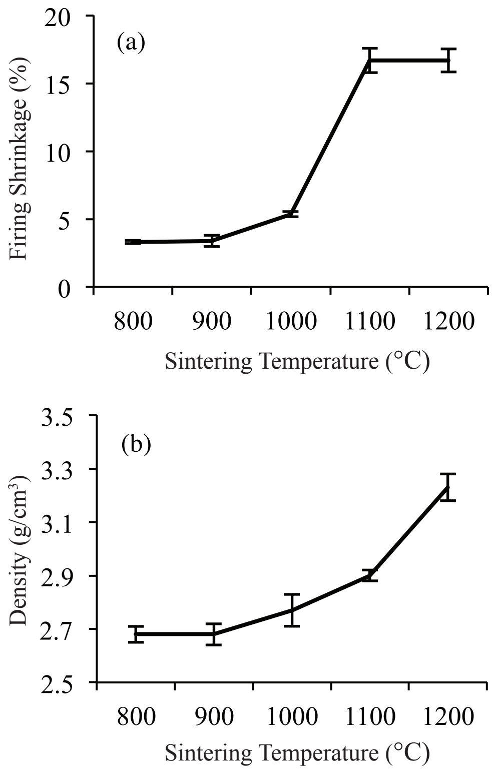

Figure 5: Effect of (a) firing shrinkage and (b) density of the ball clay at different temperature

1200°C which is around 17% as shown in Figure 5(a). Solid state sintering process are used to develop atomic bonding between particles by a diffusion mechanism (Warren, 1992; Barsoum, 1997) then followed by grain growth that will create a dense structure with significant increase in shrinkage.

The density of ceramic pieces increased from 2.68 to 3.23 with increasing sintering temperature from 800 to 1200°C as shown in Figure 5(b). The finding shows that higher sintering temperature caused higher densification of the ceramic body. Development of dense grain structure was due to the diffusion process during sintering treatment that leads to the interaction between pores of the grain boundaries (Harun *et al.*, 2013) which promotes strong mutual bonding (Rahman, 2005) hence increasing the strength of ceramic pieces. The density result of the ceramic body was closely related to the porosity and water absorption properties.

Porosity and Water Absorption

Porosity and water absorption of ceramic piece are important parameters that determine the usable of ceramic products. High density, a low porosity and water absorption ceramic product is desirable when producing ceramic products. It is clearly seen that, density was inversely proportion to porosity and water absorption. The amount of porosity decreased from 60% to 11% while water absorption capability decreased from 22% to 16% when sintering temperature was increased from 800 to 1200°C as shown in Figure 6. Lower porosity indicates that the ceramic piece was consolidated at higher temperature, thus decrease the amount of water absorbed by samples.

Conclusion

Ball clay from Kg. Dengir contains common minerals found in clay samples such as kaolinite, quartz and hematite. This ball clay is highly potential for producing ceramic products due to good quality of the ceramic piece (no cracking or defect) obtained during casting process. Temperature highly influenced the properties of ceramic piece. The shrinkage and density of ceramic piece was increased while porosity and water absorption decreased with increasing sintering temperature. The best sintering temperature are above 1000°C which is suitable for producing ceramic products due high densification and low water absorption.

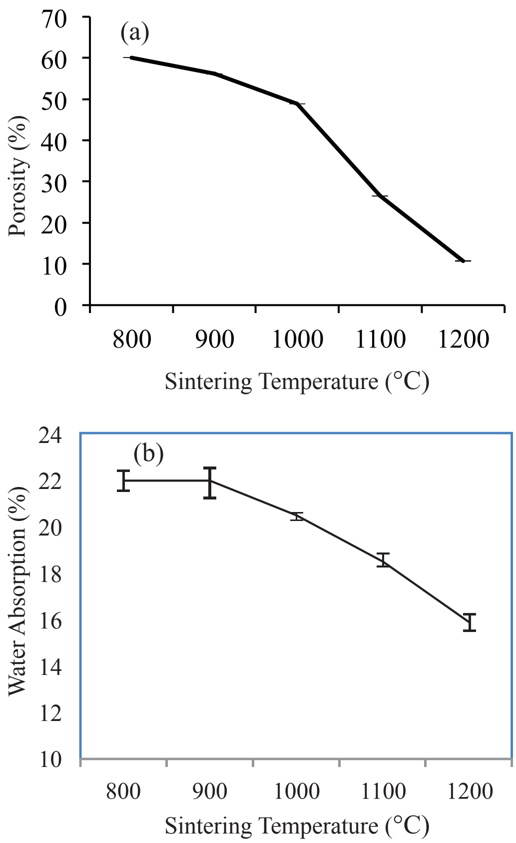

Figure 6: Effect of (a) porosity and (b) water absorption of the ball clay at different temperature

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