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FABRICATION OF MAMBONG POTTERY BY USING SLIP CASTING METHOD

by

AMANINA IZZATI BINTI AHMAD TERMIZI

A report submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science Materials Technology

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FABRIKASI TEMBIKAR MAMBONG DENGAN MENGGUNAKAN KAEDAH ACUAN SLIP

ABSTRAK

Di Malaysia, terdapat beberapa jenis tembikar yang dikenali seperti tembikar Sayong di Kuala Kangsar, Perak, tembikar Terenang di Tembeling, Pahang, tembikar Sarawak dan tembikar Mambong di Kuala Krai, Kelantan. Tembikar Mambong diperbuat daripada teknik yang menggunakan kaedah tradisional. Dalam kajian ini, kaedah acuan slip telah diperkenalkan dan digunakan untuk menghasilkan tembikar. Kaedah ini menggunakan acuan berliang yang dapat menyerap kandungan air dari slip tanah liat. Objektif kajian ini adalah untuk menghasilkan sampel tanah liat Mambong dengan menggunakan kaedah acuan slip dengan komposisi air yang berbeza dan mengkaji kesan dan sifat-sifatnya. Kemudian, sampel telah dikaji melalui nilai graviti khusus untuk slip tanah liat (S.G.), proses acuan, pengecutan linear untuk sampel yang kering dan yang telah dibakar, ketumpatan dan peratus keliangan dan kekuatan sampel tanah liat.

Dalam kajian ini, tanah liat Mambong telah diambil dari Kampung Mambong dan saiz zarah tanah liat itu dikawal hanya kepada bawah 425μm. Slip tanah liat bercampur dengan air pada komposisi yang berbeza dan dilabelkan sebagai 50C50W, 60C40W, 70C30W dan 80C20W dengan penambahan 0.7% natrium silikat, Na_2SiO_3 sebagai penyahgumpal. Slip tanah liat ditinggal untuk satu hari untuk proses penuaan. Kemudian, slip tanah liat telah dituangkan ke dalam acuan sehingga slip tanah liat mengeras sebagai badan hijau (sampel tanah liat), dan ia boleh dikeluarkan daripada acuan. Selepas kering sepenuhnya, sampel dibakar pada suhu 900°C dengan kadar pemanasan pada 4°C seminit dalam relau.

Dari kajian ini, 70C30W adalah komposisi yang optimum untuk digunakan dalam penghasilan tembikar dengan kaedah acuan slip. 70C30W mempunyai nilai S.G. lebih tinggi pada 1.78 yang berada dalam julat terbaik untuk nilai S.G. berbanding 50C50W dan 60C40W. Masa yang diambil untuk mengeluarkan 70C30W adalah yang paling singkat. 70C30W juga mempunyai pengecutan linear yang rendah untuk sampel yang kering dan yang telah dibakar pada 5.81% dan 0.77% yang juga lebih rendah daripada tanah liat Sayong yang mempunyai 6% dan 10% untuk pengecutan linear untuk sampel yang kering dan yang telah dibakar. Modulus yang diperlukan untuk sampel patah (MOR) oleh 70C30W menunjukkan nilai tertinggi pada 36.91 N/mm^2 berbanding 60C40W yang mempunyai 22.96 N/mm^2.

Walau bagaimanapun, ujian ketumpatan dan peratus keliangan menunjukkan bahawa 70C30W mempunyai ketumpatan yang rendah dan nilai yang rendah untuk peratus keliangan manakala 60C40W mempunyai ketumpatan yang tinggi dan nilai yang tinggi untuk peratus keliangan yang di mana nilai ketumpatan 60C40W sepatutnya terbalik dengan 70C30W. Hal ini disebabkan oleh kesilapan yang telah berlaku semasa ujian dijalankan seperti ralat penentukuran. Lebih banyak penyelidikan dan kajian mengenai tembikar Mambong perlu dilakukan untuk mendapatkan parameter yang optimum dalam menghasilkan tembikar yang berkualiti tinggi.

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ABSTRACT

In Malaysia, there are several types of potteries known which are Sayong pottery in Kuala Kangsar, Perak, Terenang pottery in Tembeling, Pahang, Sarawak pottery and Mambong pottery in Kuala Krai, Kelantan. Mambong pottery was being made by traditional technique. In this research, slip casting method was introduced and used in producing pottery. This method used porous mold which able to absorb water content from the clay slip. The objective of this research was to fabricate the Mambong clay sample by using slip casting method with different composition of water and study its effect and properties. Then, the samples were characterized by its specific gravity (S.G.) of clay slip, casting process, drying and firing linear shrinkage, density and porosity and strength of the clay samples.

In this research, Mambong clay was taken from the Mambong Village and the particle size was controlled to below 425µm. The clay slip was mixed with water at different composition which labelled as 50C50W, 60C40W, 70C30W and 80C20W samples with addition of 0.7% of sodium silicate, Na_2SiO_3 as deflocculant. The clay slip was left for one day for aging process. Then, the clay slip was poured into the mold and as the clay slip solidified as green body (clay sample), it was ready to be removed from the mold and left for drying. The samples were sintered at 900°C with heating rate at 4°C per minute in the furnace.

The samples were characterized by its raw material and fired sample. From this research, 70C30W was the optimum composition to be used in fabricating pottery by slip casting method. 70C30W have the higher S.G. of clay slip at 1.78 which within the range of the best S.G. of clay slip compared to 50C50W and 60C40W. The time taken for sample removal for 70C30W was the shortest. 70C30W also have the lowest for its drying and firing linear shrinkage at 5.81% and 0.77% respectively which also lower than Sayong clay drying and firing shrinkage that have 6% and 10% respectively. The modulus of rupture (MOR) of 70C30W showed the highest value at 36.91 N/mm^2 compared to 60C40W that have 22.96 N/mm^2.

However, the density and percentage of porosity test showed that 70C30W have low density and low percentage of porosity while 60C40W have high density and high percentage of porosity where the value of density should be vice versa. This was due to errors that had occurred during the test was conducted like calibration error. More research and study about Mambong pottery should be done to obtain optimum parameters in fabricating high quality of pottery.

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LIST OF ABBREVIATIONS

PoP	Plaster of Paris
MOR	Modulus of Rupture
S.G.	Specific Gravity of clay slip
ASTM	American Society for Testing and Materials

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LIST OF SYMBOLS

°C	degree Celcius
%	percentage
g	gram
wt%	weight percentage
ml	milliliter
p	density
p	porosity
cm	centimetre
µm	micrometer
g/cm^3	density
N/mm^2	modulus of rupture

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DECLARATION

I hereby declare that the work embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities or institutions.

____

Student

Name:

Date:

I certify that the report of this final year project entitled "Fabrication of Mambong Pottery by Slip Casting Method" by Amanina Izzati binti Ahmad Termizi, matric number E13A016 has been examined and all the correction recommended by examiners have been done for the degree of Bachelor of Applied Science (Materials Technology) with Honours, Faculty of Earth Science, Universiti Malaysia Kelantan.

Approved by:

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Supervisor

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Ceramic is one of the largest groups of material with the properties of non-metals and often including silicates and metal oxides. The term ceramic comes from a Greek word 'keramikos' which stand for 'burnt stuff' as most of ceramic product is produced by exposing them to high temperature (Callister & Rethwisch, 2011). Ceramic can be categorized into advanced ceramic and traditional ceramic.

Advanced ceramic consists of elecroceramic and advanced structural ceramic. The unique properties of ceramic that become attractive point to researcher to improve and engineered it to be used for advanced applications like as biomaterials and in semiconductor industries. Traditional ceramic which usually made from clay consist of tableware and pottery, brick and tile, refractories and abrasives. Currently, pottery has gained interest in society as it is a valuable heritage descended from the past social culture of certain civilization.

The art of making pottery by forming and burning clay has been practiced from the earliest civilisation. It is one of the ways to observe the development of the culture and civilisation during Mesolithic, Paleolithic and Neolithic era. Pottery can be referred as clay body form into any objects of desired shape and heated to high temperatures in a kiln to sinter the green body and become solid strengthened object (Gani et al, 2015). Green body is a body of clay that has been formed and dried but not yet undergo firing process (Callister & Rethwisch, 2011). Exposing clay body to high temperatures will remove the water content in the clay body and induced a reaction that leads to the permanent changes while increase its strength (Enoch, 2012). In Malaysia, there are several types of pottery present such as Terenang pottery, Labu Sayong, Belanga, Sarawak pottery and Mambong pottery.

Mambong pottery name's come from the Mambong village which located in Kuala Krai, Kelantan, Malaysia is one of the famous pottery produced other than Terenang pottery in Tembeling, Pahang and Sayong pottery in Kuala Kangsar, Perak. It is located near Galas River and 10 miles from Kuala Krai jetty and only can be accessible by water transport like boat. From the jetty, it took near 45 minutes to reach Mambong Village.

This pottery is fabricated by using hand forming technique which is the conventional technique in producing pottery. This pottery is one of the historical arts of Kelantan civilisation. Mambong village had been producing pottery since 238 years with products such a smoke container, round bottom water jar, squat water vessel, vessel with handles, earthenware pot and steam pot (Gani et al, 2015). This pottery production marks the development and growth of Kelantan civilisation.

The composition of Mambong clay consists of silica, iron oxide, aluminium oxide, titanium oxide, calcium oxide, sodium oxide, potassium oxide, phosphorus oxide and magnesium (Said et al, 2011). The composition of clays is a significant factor that gives effect in pottery quality and reliability (Gani et al, 2015). The pottery making process used in Mambong is slightly different from other type of pottery produced. Fine sand from river is taken and added to the grinded clay before it is being pounded again to make it even finer (Gani et al, 2015). This is the unique part of Mambong pottery.

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Nowadays, trend of pottery has change from cooking ware and kitchen utensils into iconic national heritage of Malaysia and souvenir. This can be seen as in Kuala Kangsar, Perak, Sayong pottery is massively used in handicraft industry. With the growing in the handicraft industry of ceramic and pottery, modern and advanced technology has been introduced and used in producing pottery like slip casting technique. Majority of pottery manufacturer in larger mass production more favour to use this technique because it is easy to manage and able to speed up the drying process (Gani et al, 2015).

1.2 Problem statement

Mambong pottery is being produced by hand forming technique. This traditional technique used three different methods which are coil, pinch and in shaping stage of the pottery. Potters can shape the clay into any desired shape by using hand and pottery tools like carving knife and rib. Although this technique is valuable as its picture the potter's creativity and skill, it has several disadvantages.

By hand forming technique, high variation between pottery products is present. This is due to the movement of hand in shaping stage which cannot be standardized. High variation between products will lead to low quality of production. Moreover, long time is taken in shaping stage of the plastic clay by hand forming. A larger mass production cannot be produced in short time, thus, unable to meet the high demand of pottery product. Low in quality and mass production of Mambong pottery which affected by the traditional technique of hand forming brings to diminish of reputation of Mambong pottery.

To solve the problems encountered when using this traditional technique, slip casting method is used in the fabrication of pottery. Slip casting is where a clay slip

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is cast in the porous mould which will absorb the water content in the slip as it casted. This method able to reduce the solidification time, thus, can increase mass production. Furthermore, by using mould, almost identical size and dimension of pottery can be made which improved the quality of the pottery product itself.

1.3 Objective

i. To fabricate Mambong pottery by using the slip casting method.

ii. To study the effect of difference water composition on the pottery sample properties by measuring the specific gravity slip of the clay slip, time taken of sample removal from mould, shrinkage process, density and porosity and the strength of pottery sample.

1.4 Expected outcome

With slip casting technique, more consistent in size and dimension of pottery product can be obtained. Besides, the stability of pottery can be improved due to even and unvarying thickness. The fineness of pottery is implied by the approximately same weight between pottery products due to uniformity of pottery's body wall (Haron et al, 2014). This technique use PoP as a mould which is a porous material. The water from the clay slip was absorbed by the plaster. Thus, the solidification or casting time for pottery can be reduced and the plaster also can be used for about 100 times (Schafföner & Aneziris, 2011). The production rate of pottery can be multiplied with low cost production.

Increase in number of production of Mambong pottery with more enhanced quality can increase the attractiveness to own of this pottery and save it from being lost in time and depreciated.

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CHAPTER 2

LITERATURE REVIEW

2.1 Ceramic

Ceramic is a materials that usually made by firing and burning in kiln at elevated temperature for example of product is pottery. Pottery had been traced manufactured and used since the earliest human civilisation. Burn clayware has been found as industrial product of Egypt since 15000 before century. Ceramic can be categorized into two types which are advanced ceramic and traditional ceramic.

2.1.1 Advanced ceramic

Advanced ceramic can be differentiated into two classes which are electroceramic and advanced structural ceramic. Electroceramic consist of conductive ceramic, optical ceramic, magnetic ceramic and electronic ceramic. This class of ceramic material is usually used for its electrical properties, for example, dielectric ceramic which able to store large amount of electrical energy relatively to small volume. Advanced structural ceramic consist of nuclear ceramic, bioceramic, automotive ceramic and tribological ceramic. For example in bioceramic, ceramic material is used as implant in dental or medical field. Ceramic material is bio-inert which make it suitable as an implant. The other type of ceramic is traditional ceramic which was the focus of this research.

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2.2 Traditional ceramic

Traditional ceramic is based on silicate, silica and other mineral oxides found in nature and which also known as silicate ceramic. There are several types of raw materials that commonly used in traditional ceramic which are kaolinite, feldspar, silica and clay. The material present in the ceramic can affect the physical and mechanical properties of the ceramic.

2.2.1 Kaolinite

Koalinite, $Si_2Al_2O_5(OH)_4$ or Al_2O_3, $2SiO_2$, $2H_2O$ is the most common among the minerals used in ceramics. This is due to its high refractoriness and possible use in raw-materials mixtures designated for fast firing. It also has good deflocculation (Sokolar, 2012).

2.2.2 Feldspar

Feldspar which is fluxing agent that a group of aluminosilicate materials. It contains potassium, sodium and calcium ions (Callister & Rethwisch, 2011). It acts as defluoccant. Its properties is necessary to increased fluidity of clay slip, thus, less water is required (Wardell, 2007).

2.2.3 Silica

Silica, SiO_2, is a polymorphic raw material found in nature in an amorphous or crystalized form. Quartz is an example of silica in crystallized form. It gives high mechanical strength to the clay products. The form of silica present can determine the thermal properties of the silicate ceramic (Boch & Nièpce, 2006). The main raw material that mostly used in traditional ceramic is clay.

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2.3 Clay

Clays are hydrated silico-aluminous minerals, for example of product is red clay in manufactured terra cotta (Boch & Nièpce, 2006). The clay can be found at the place where it is formed or by the river bank as it is always carried away by the rivers. When the clay is transported by water, it became finer and finer due to impact with the stone and rocks of river. The clay used in Mambong pottery is taken from Galas River (Gani et al, 2015). Clays have hydroplasticity properties that make clay become plastic as water is added. This is very suitable propertied especially in pottery fabrication process as desired shape can be obtained (Callister & Rethwisch, 2011). The types of traditional ceramic products are usually made from clay based products including brick and tile, refractories, abrasives, cement, whiteware, earthenware and pottery.

2.4 Pottery

Pottery is made by forming a plastic clay into desired shape and expose them to high temperature in kiln to remove water content in the clay and lead to permanent shape simultaneously increase its mechanical properties like strength (Enoch, 2012). The art of pottery have been developed from early civilisation for many purpose such as for practical purpose like vessels for food and storage and as expressions of the instinct for belief ritual and art (Breuer, 2012). There are several type of pottery exist in Malaysia which are Terenang pottery in Tembeling, Pahang, Labu Sayong in Kuala Kangsar, Perak, Belanga, Sarawak pottery and Mambong pottery. The types of pottery are shown in Figure 2.1.

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a.

b.

c.

d.

e.

Table 2.1 Different type of pottery in Malaysia: a) Labu Sayong b) Terenang c) Belanga d) Sarawak pottery e) Mambong pottery

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Terenang pottery is usually in angular-shaped and applied mostly for storage of water. It has concave neck and a convex body. Terenang is the famous pottery from Pahang compare to other pottery such as censer (bekas perasap) and large jar (tempayan) that are also produced in the same place in Tembeling, Pahang (Hamdzun & Narimah, 2013).

Labu Sayong pottery is produced in Kuala Kangsar, Perak. The pottery is a black-coloured gourd-shaped clay jar which usually used to store and cool water. The water stored inside the clay pitcher is colder than the regular water and it is believed able to refresh the body when drink it (Hamdzun et al, 2014). The pottery is fabricated by hand building-pinching technique.

Belanga is one of the types of pottery which commonly found in rural area of Malaysia. It has a round base and a wide rim and often used in cooking meals. Next, Sarawak pottery has a long neck and used mostly for decoration purpose. This pottery is usually made by Iban, Murut, Kelabit and other by Chinese potters. Other type of pottery in Malaysia is Mambong pottery in Kelantan.

2.5 Mambong pottery

In Kelantan, Malaysia, Mambong pottery had been traced since 1868 years ago (Said et al, 2011). These made the Mambong pottery as the cultural heritage of Kelantan. The pottery is a fashioned from clay and characterized by red shade. This pottery is first introduced by family of Maimunah bt. Puteh (Tok Bara). According to Ramli b. Mat Isa, all four generations in family of Tok Bara (Maimunah bt. Puteh, 1868-1969), the basic skill in pottery in Maimunah bt. Puteh is inherited from the previous generations and now descended by the current generation (Tajul et al, 2011). Among the Mambong products are steam pots and covered water jars.

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The composition of Mambong clay consists of silica, iron oxide, aluminium oxide, titanium oxide, calcium oxide, sodium oxide, potassium oxide, phosphorus oxide and magnesium (Said et al, 2011). The reddish colour of Mambong clay has been proven due to present of red iron oxide and the glossy effect of the finished product is due to present of titanium oxide from the sand of Galas River.

Despite the problem encountered by Mambong pottery due to the conventional technique of hand forming used in its pottery fabrication, Mambong pottery has its uniqueness which can be seen in its processing method. Finer sand from river is taken and added to the grinded clay and to be pounded again, thus, producing the finest pottery product (Gani et al, 2015). Although Mambong pottery is not as famous as Sayong pottery in Perak but it has unique and special feature. Mambong pottery produced is a durable pottery which cannot be broken easily (Hamdzun & Narimah, 2013). It is also a historical art and proved in development of culture in Kelantan. It is important and crucial to preserve the art and tradition of Mambong pottery so that it will not extinct due to era of globalisation (Said et al, 2011).

2.6 Technique used in pottery fabrication

There are several techniques used in pottery fabrication since earlier time of its being introduced as basic application in daily life until this current new era of urbanisation. The first technique used by ancient civilisation is hand building or hand forming, followed by wheel throwing which used potter's wheel to give shape to plastic clay. With aid of technology, the technique evolved to jollying and jiggering. Then, potters turn to casting technique in fabricating pottery. This technique is

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mostly used by manufactures of clay based product like pottery in large mass production.

2.6.1 Hand building

Pottery fabrication techniques which is hand building or hand forming that consists of three different ways such as coil, pinch and slab. Coil method is stacking long ropes of clay on top of each other to create a desired form. Pinch method is done by pinching the clay between thumb and forefinger in creating a form. In slab method, form is created by using thin sheets of clay and hit by wooden spatula. Mambong pottery is fabricated by using hand forming technique. This conventional way have created a problem due to low mass production of pottery cannot match the increasing demand of its products. The quality of the pottery also decline due to non-uniform in thickness of pottery wall and have high variation between products.

2.6.2 Wheel throwing

Next technique is wheel throwing which is a form of clay that created on a potter's wheel and the shape of clay is affected by the spinning motion of the wheel. Both hand forming and wheel throwing method is not suitable in producing higher mass production. The time taken for pottery fabrication is longer than other technique like slip casting make it more favourable in current era.

2.6.3 Jollying and jiggering

Other technique is jiggering and jollying. This technique is basically like a potter's wheel only it is used to produce more uniform products semi-automatically or automatically compare to hand forming and wheel throwing. But jiggering and jollying has limitation on shape. It is usually used for one piece mould and the

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cylinder shape is not suitable to fabricate by using this technique (Norsker & Danisch, 1991). Like wheel throwing technique, this technique also has uneven thickness of pottery product.

2.6.4 Casting

Casting technique is one of the frequent techniques used by manufacturer of large mass production of pottery. There are several types of casting technique which are tape casting, pressure casting, consolidation of concentration of suspension and slip casting.

2.7 Slip casting

With current and advanced technologies, slip casting technique had been introduced as one of the pottery fabrication technique. This method consists of casting a suspension called slip in a porous mould, generally made by plaster usually Plaster of Paris and the migration of water in slip into the pores of mould will form a consolidated layer of clay particles on the mould surface known as cast (Boch & Nièpce, 2006). Slip is a suspension of clay or other non-plastic materials in the slip (Callister & Rethwisch, 2011).

The main advantages of this technique are complexity of the forms can be produced by using multi-part mould, it is low cost technique and the use of perfectly dispersed suspensions in technical ceramics lead to dense and homogeneous green microstructures (Boch & Nièpce, 2006). The mould from the Plaster of Paris also can be used again and again. With this technique, the mass production of Mambong pottery can be increase and more fine pottery can be made.

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CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

The material needed in this research were Plaster of Paris (PoP) to form a multi-part mould for slip casting process, clay which was taken from Mambong village and sodium silicate, Na_2SiO_3 which acts as deflocculant to increase the fluidity and decrease the viscosity of the clay slip.

Tools also were required in fabrication of pottery by using slip casting such as tube band to cottle the multi-part mould, wooden bats, soap and soft sponge, weighing scale, blunger machine, decorating tools which can be from natural things like wood and stone, carving knife and rib.

3.2 Methods

The methodology of slip casting was concisely explained in this sub-chapter in order to easy comprehend about the steps taking in this technique. Slip casting technique consists of three steps which are multi-part mould making, clay slip preparation and slip casting process.

3.2.1 Multi-part mould making

One Mambong pottery product was taken as a model. PoP was mixed with water with suitable proportions to obtain slurry called plaster to form a mould. Prior to moulding, spare was an important element required for this step which was literally an extension of plaster added to model to facilitate moulding (Wardell,

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2007). Its function as the opening for pouring and draining the slip. The spares were prepared for top and base of the model.

The model was soaked in water if it was dried and center line was found. The entire model and spares was soft soap and the spared was attached at the top and base of model by using glue. A band larger enough for the model to make a mould was prepared. The model was placed on its side with rolls of clay below it and adjusted until the center line was level. The plaster bats were cut to fit the model and spares on the both side. When it was done, the bats were soft soap. Rolls of clay were lay across each other below the center line of the model. The plaster bats were gently pushed until they become level with the center line.

Next, the walls were soft soap and assembled around the bedded model which can be from a wooden board. The wall was tied with string to create tension, plaster was poured and left for setting. After that, the walls were removed and the outside of the mould was cleaned. The mould and model was turned over and cleaned from any contaminants before the plaster for second half was poured.

To make the mould for the base, both sides was kept together and the base spare was removed. The area was soft soap and the base was cottled with roofing lead and plaster was poured. It was leave to dry the same way as the drop-out mould (Wardell, 2007). Before undergo slip casting process, the mould was made sure to be dried. All the parts of the mould was assembled and cottled together with inner tube bands. This to prevent the mould seams from opening during the slip pouring (Wardell, 2007). The flow of process in multi-part mould making was shown in Figure 3.1.

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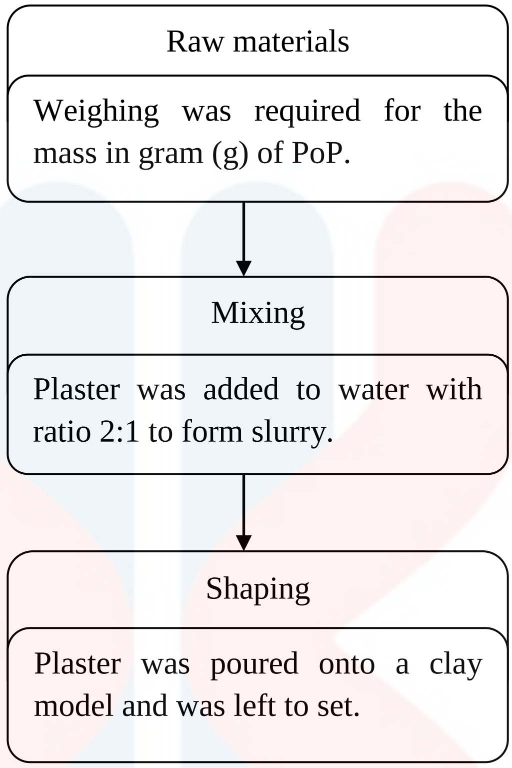

Figure 3.1 Flow chart of multi-part mould making

3.2.2 Clay slip preparation

Clay slip was made by mixture of clay powder and water at adequate amount. The ratio of solid content or clay must be larger than the ratio of water for example the good composition of clay to water is at 60:40 ratio (Ahmad et al, 2014). In this research, four different composition of clay to water ratios at 50:50, 60:40, 70:30 and 80:20 was mixed and labelled as 50C50W, 60C40W, 70C30W and 80C20W respectively. Blunger machine was used to grind clay and producing the slip which can reduce the time and energy consume during the process. The slip was leave for one day to become slurry. Deflocculant sodium silicate was added in small amount at 0.7% from the clay mass. The flow of process in slip preparation was shown in Figure 3.2.

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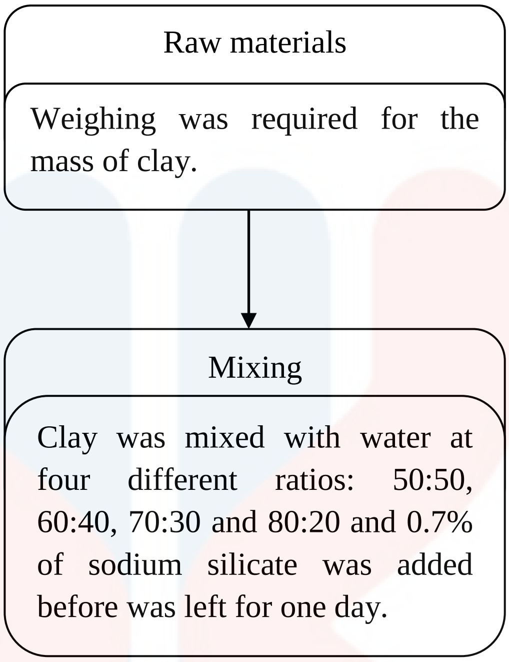

Figure 3.2 Flow chart of clay slip preparation

3.2.3 Slip casting process

i. Mould filling and casting time

Slip was poured into the mould slowly until the mould was full to prevent air bubble formation that maybe trapped during the slip making process (Ahmad et al, 2014). Slip need to be added into the mould after certain time due to shrinkage of slip as the water was being absorbed by the porous mould. The slip was leave for the sample to form until the shell wall was dried at desired thickness.

ii. Tipping and draining

The slip was tipped out steadily into a bucket using circular motion swilling the remaining slip around the mould. This will increase the fluidity of slip and drain most evenly from mould. The mould was reversed and spares are cut to prevent the slip from fall back and stick to the dried sample (Wardell, 2007).

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iii. Emptying mould

The sample was removed from the mould after thirty minutes of tipping by untying the inner tube band. Two side halves was lifted together off the base and placed on its sided, top half side was removed and replaced as the base. The remaining half was lifted and the sample was removed.

iv. Fettling and sponging

Fettling line formed due to the multi-part mould was removed by using sponge.

v. Drying and firing

The green body was leave at room temperature to dry before the first firing was done in the furnace for half to one hour. The carving can be done on the green body. The firing must be done slowly to ensure the green body that was still wet to dry first. For producing bisque firing, the temperature was between 850°C and 900°C was used. The bisque was left cool in the furnace and ready for decoration and glazing if needed (Ahmad et al, 2014). The flow of slip casting process was shown in Figure 3.3.

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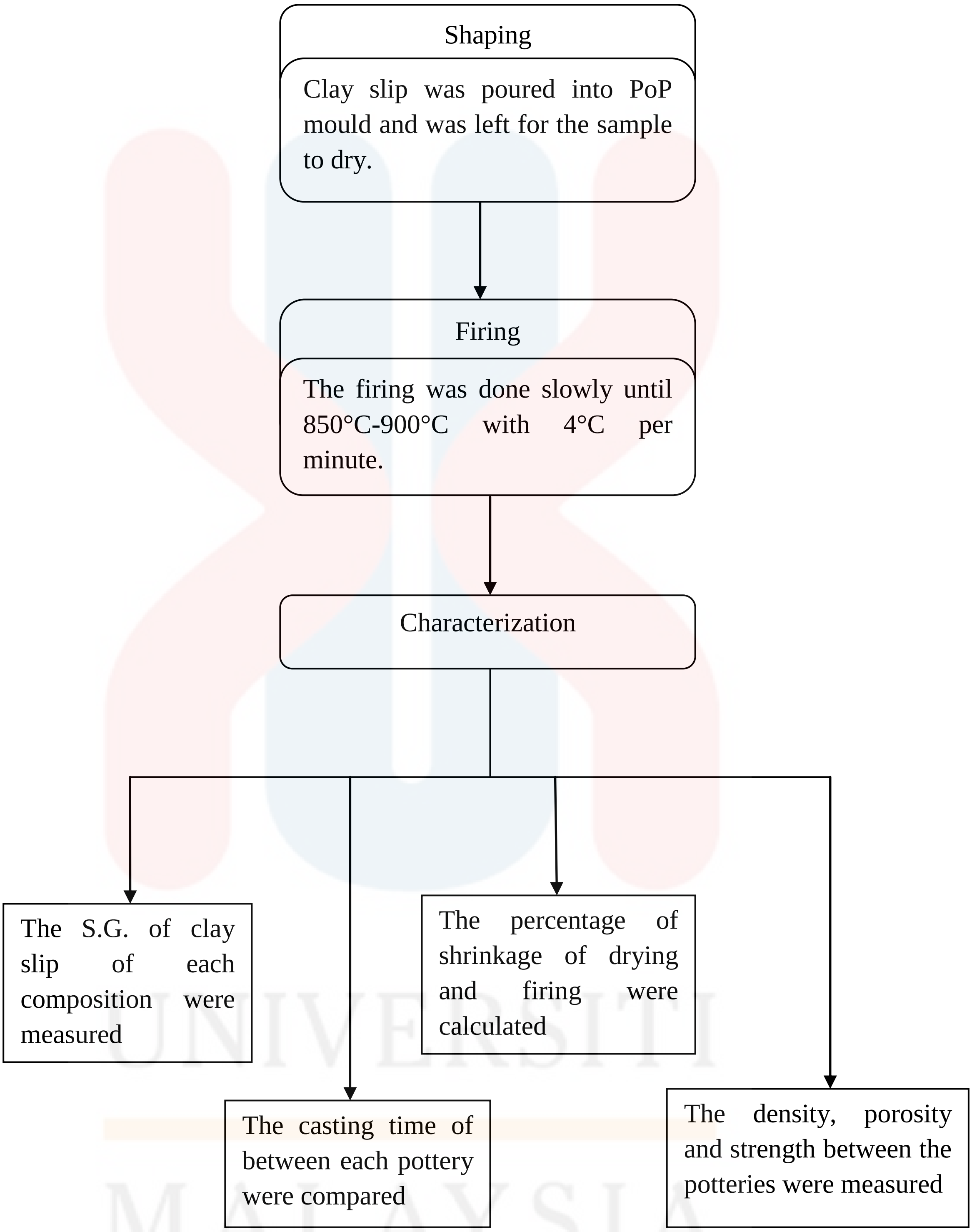

Figure 3.3 Flow chart of slip casting process

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3.3 Characterization of Mambong clay samples

The Mambong clay samples was characterized before and after the firing of process by its specific gravity of clay slip, casting process, physical properties like colour, drying and firing linear shrinkage of samples, the density, porosity and the strength of samples. The characterization was done to compare between four different compositions of clay to water in weight percentage (wt%) in order to obtain the optimum composition by slip casting method.

3.3.1 Specific gravity of clay slip

In this test, the weight of empty 250 ml beaker and the weight of the beaker with clay slip were taken. The density of the clay slip can be obtained calculating the difference in solid weight in colloids over 250 ml beaker as shown in Equation 3.1. The specific gravity (S.G) slip of clay was range from 1.75-1.80.

$$S.G = \frac{(a-b)}{250} \qquad \text{Eq. 3.1}$$

where,

a = weight of empty beaker

b = weight of beaker with clay slip

3.3.2 Casting process of clay samples

During this process, the time taken for the sample to form and able to remove from mould was recorded. As the ratio of water to clay was different indicate different rate of water content was absorbed by the porous mould of PoP. Thus, the time taken for the sample to form and able to remove from mould was varies between each composition.

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3.3.3 Percentage of linear shrinkage of clay samples

The shrinkage process was closely related with the composition of water present in clay slip. Higher composition of water will cause rapid shrinkage which can lead the samples to crack and warpage. In this test, the percentage of linear shrinkage of samples was taken by using vernier calliper and calculated by using Equation 3.2. This test was conducted by using ASTM C326-03 Standard Test Method for Drying and Firing Shrinkages of Ceramic Whiteware Clays.

$$\text{Percentage of shrinkage of sample} = \frac{(L_0 - L_1)}{L_0} \times 100\% \qquad \text{Eq. 3.2}$$

where,

L_0 = Length initial of sample

L_1 = Length of sample after drying or firing

3.3.4 Density and porosity of clay samples

The porosity of pottery was related to the density of the pottery. The higher density showed that the pottery has small porosity. It also indicated the compactness of the pottery. The density and porosity of the clay sample was calculated by using Archimedes' principle. This test was run following the ASTM Standard C373-88 (2006) "Standard Test Method for Water Absorption, Bulk Density, Apparent Porosity and Apparent Specific Gravity of Fired White Ware Product" ASTM International, West Conhohocken, PA, 2006: DOI: 10.1520/C0373-88R06.

There are three measurements that were taken which are dry weight as W_1, weight of ceramic body in water as W_2 and the weight of water-saturated ceramic

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body as W_3. The weights of samples are measure by using density kit. Following the Archimedes' principle:

The bulk density was calculated by using the Equation 3.3.

$$\text{Bulk density}, p = \frac{M_d}{M_w - M_s} \times p_{water} \qquad \text{Eq. 3.3}$$

where,

M_d = mass of air dried sample

M_w = mass of immersed sample in air

M_s = mass of immersed sample in water

p water = density of water, 0.9982 kg/cm^3

The percentage of porosity also was calculated by using the Equation 3.4.

$$\text{Porosity}, p = \frac{(M_w - M_d)}{M_w - M_s} \text{ x } 100 \qquad \text{Eq. 3.4}$$

3.3.5 Strength measurement clay samples

The strength of Mambong clay sample of each composition was measured by measuring its modulus of rupture (MOR). This test was conducted by using 3-point bending machine following standard ASTM C1161-02C Standard Test Method for Flexural Strength of Advanced Ceramic at Ambient Temperature. Mould with specific dimensions for the test was done to obtain smaller sample pottery with standard size used for the test. The dimensions of sample are 15 cm in length, 1 cm in thickness and 2.5 cm in width.

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter aim to verify that more fine pottery can be produced by using slip casting compared to traditional method like pinching and throwing. The property of pottery sample which varies in composition of water to clay was investigated by conducting several characterization process and tests that can be grouped into raw material characterization and fired sample characterization. The data obtained are discussed in this chapter.

4.2 Raw material characterization

The particle size of Mambong clay used in this research was controlled to below 425 μm by using screening sieving. Weight percentage was used in varying the composition between clay and water. All the samples were labelled as 50C50W, 60C40W, 70C30W and 80C20W. 0.7% of sodium silicate, Na_2SiO_3 was used in preparation of clay slip. Some of characterizations were done before the firing process like specific gravity of clay slip (S.G) and the casting test.

4.2.1 Specific gravity (S.G.) of clay slips

This test was conducted to measure the specific gravity of the clay slip in order to know the most suitable for slip casting technique. The Figure 4.1 show the clay slip of one of the composition of clay to water which used in this test. The result of S.G clay slip value of samples was presented in Table 4.1.

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Figure 4.1 Clay slip used to measure S.G. of clay slip

Table 4.1 showed the result of S.G. of clay slip test, 70C30W had S.G of clay slip value of 1.78. The clay slip of 50C50W and 60C40W had S.G of clay slip value of 1.42 and 1.54 respectively. 50C50W with S.G of clay slip value 1.42 was too slurry and have higher water composition in clay slip, thus, produced a sample that has a crack even when it was still in the mould which shown in Figure 4.2.

Table 4.1 Results of S.G of clay slip test

Sample	S.G value
50C50W	1.42
60C40W	1.54
70C30W	1.78
80C20W	-

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Figure 4.2 Crack present in green body of 50C50W due to present of too much water contents

The S.G of clay slip for 80C20W cannot be calculated. This is due to the mixture of clay and water for 80C20W was not forming a clay slip but a bulk of clay which showed in Figure 4.3. Thus, 80C20W was obviously not suitable for slip casting method.

Figure 4.3 The bulk of clay of 80C20W

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Figure 4.4 showed the comparison of S.G. value between 50C50W, 60C40W and 70C30W, the S.G of clay slip was seen increased from 50C50W to 70C30W. Nature of clay slip was very essential that it must have high S.G of clay slip value yet very fluid and pourable (Callister & Rethwisch, 2011). The best S.G of clay slip value was in the range of 1.75 to 1.80 (Ahmad et al, 2014).

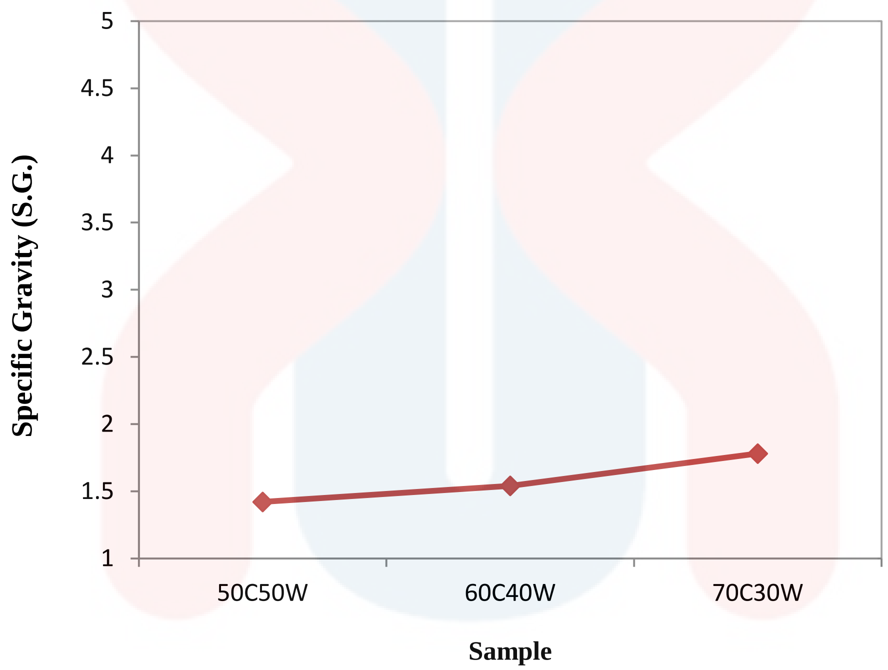

Figure 4.4 Comparison of S.G of clay slips value between 50C50W, 60C40W and 70C30W

If the S.G slip value was lower than 1.75, this indicated that the clay slip was too slurry and more clay was needed to add into the slip. If the S.G clay slip value was more than 1.80, this indicated that the clay was too thick or viscous and more water needed to be added to decrease its viscousity and increase its fluidity.

The most suitable clay slip to be used in making pottery by slip casting method was the clay slip of 70C30W which has S.G clay slip value of 1.78. The clay slip of 50C50W and 60C40W which have S.G clay slip value of lower than 1.75 was not suitable for slip casting because it was too slurry.

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4.2.2 Casting test

This test was conducted during the slip casting process. In this test, the time taken for samples able to be removed from mould was observed. The time taken for the sample able to be removed from mould was recorded by using stopwatch and was presented in Table 4.2. The differenced in composition of clay and water can gave impact on the time and ability of the sample removal from mould (Sahab et al, 2016).

The result from this test was affected by the rate of drying process of sample which was influenced by several factors like the rate of absorption of water through the clay slip into the mould and the evaporation of water from the surface (Henry, 1945). Higher composition of water in clay slip slowed the rate of drying process because more water have to be absorbed from the clay slip compared to lower water composition, thus, increased the time taken to remove the sample from mould.

Table 4.2 Time taken for samples to be removed from mould

Sample	Time taken (hour)
50C50W	12
60C40W	2
70C30W	1
80C20W	-

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The time taken of 70C30W, 60C40W and 50C50W were 1 hour, 2 hours, and 12 hours respectively. The samples in this research were differ in the composition of water, thus, the result obtained were varies between samples. Higher composition of water will have more water to be absorbed by the mould and increased the sample solidification time (Sahab et al, 2016). This can be seen from 50C50W which had slowed rate of the drying process of sample, thus, increased the time taken of sample to be removed from the mould.

On the other hand, 70C30W had the lowest time taken compared to others sample. Less water composition in clay slip of 70C30W were absorbed by mould, thus, fasten the drying process of sample. This resulted in decreasing of time taken of the sample to be removed from mould. The 80C20W cannot be tested as it was not in the clay slip form. This was due to higher composition of clay compared to water. The comparisons of the time taken between the three samples were showed in Figure 4.5.

Figure 4.5 showed the time taken to remove the sample from the mould. The time taken was decreased as the composition of water in clay slip was decreased. Low water composition can slow up the rate of drying process of sample, thus, increased the time of sample to be fully formed. The highest time taken recorded was when to remove 50C50W sample from mould while the shortest time taken was observed on 70C30W.

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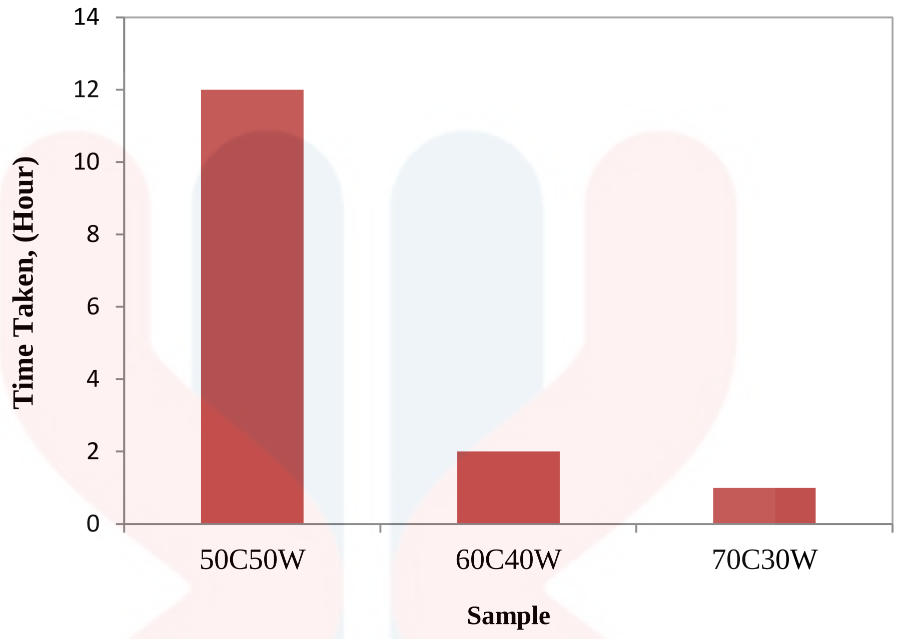

Figure 4.5 Time taken for sample removal from mould

4.3 Fired sample characterization

The samples are sintered in furnace with heating rate at 4°C per minute and soaking for 5 hours at 900°C. The changes in colour of ceramic sample before and after firing was observed and shown in Figure 4.6 and Figure 4.7 respectively. The reddish-brown colour was obtained after sintering process. This was due to present of mineral composition of red iron oxide in Mambong clay (Said et al, 2011).

Sintering process can affected the physical and mechanical properties of the samples. Several characterizations were done with fired clay sample such as percentage of drying and firing linear shrinkage analysis, density and porosity and modulus of rupture (MOR) of samples.

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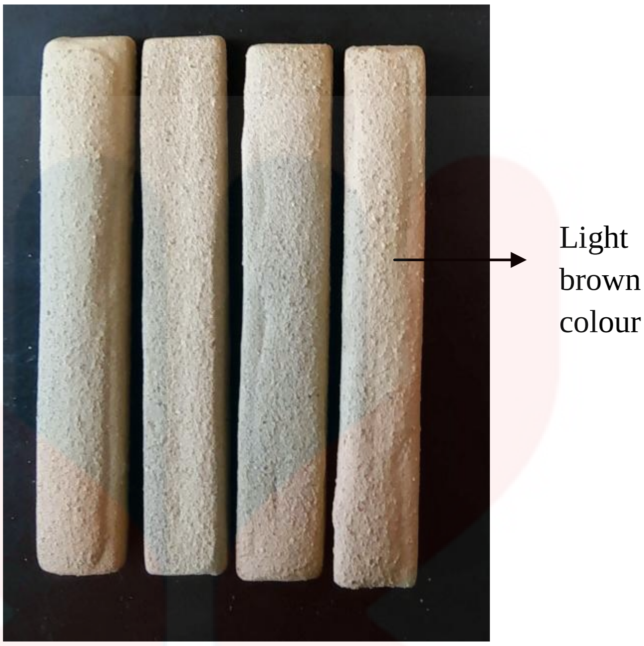

Figure 4.6 Mambong clay samples before firing process

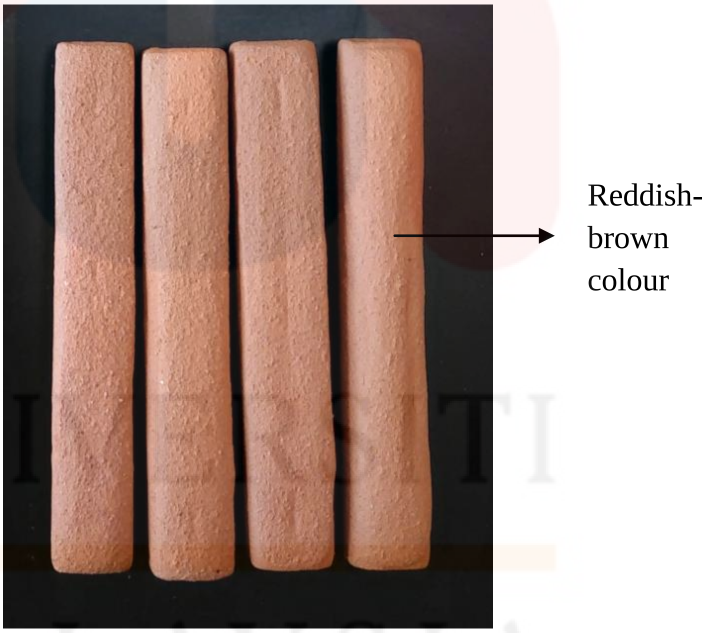

Figure 4.7 Mambong clay samples after firing process

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4.3.1 Percentage of linear shrinkage

The length of sample was measured before and after the firing process in order to obtain the firing shrinkage of sample while the drying shrinkage was calculated by measuring the length of mould and the length of sample before it was fired. The percentage of drying and firing shrinkage were showed in Table 4.3 and 4.4 respectively. The comparison of the both shrinkages between 60C40W and 70C30W were showed in Figure 4.8.

Table 4.3 Percentage of drying linear shrinkage of 60C40W and 70C30W

Sample	The percentage of drying linear shrinkage (%)
50C50W	-
60C40W	6.08
70C30W	5.81
80C20W	-

Table 4.4 Percentage of firing linear shrinkage of 60C40W and 70C30W

Sample	The percentage of firing linear shrinkage (%)
50C50W	-
60C40W	0.96
70C30W	0.77
80C20W	-

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60C40W had shrunk to 6.08% during drying process compared to 70C30W which shrunk to 5.81%. As for firing shrinkage, 60C40W have 0.96% while 70C30W have 0.77%. The Mambong clay 70C30W had lower percentage of drying shrinkage than Sayong clay. The percentage drying shrinkage of 70C30W was 5.81% compared to Sayong clay that had 6% (Oskar, 2015). But for 60C40W, the drying shrinkage was approximately same with Sayong Clay at 6.08%. For firing shrinkage, Sayong clay had percentage at 10% (Oskar, 2015). This showed that Sayong clay had higher percentage of firing shrinkage than both Mambong clay 60C40W and 70C30W which have 0.96% and 0.77% respectively.

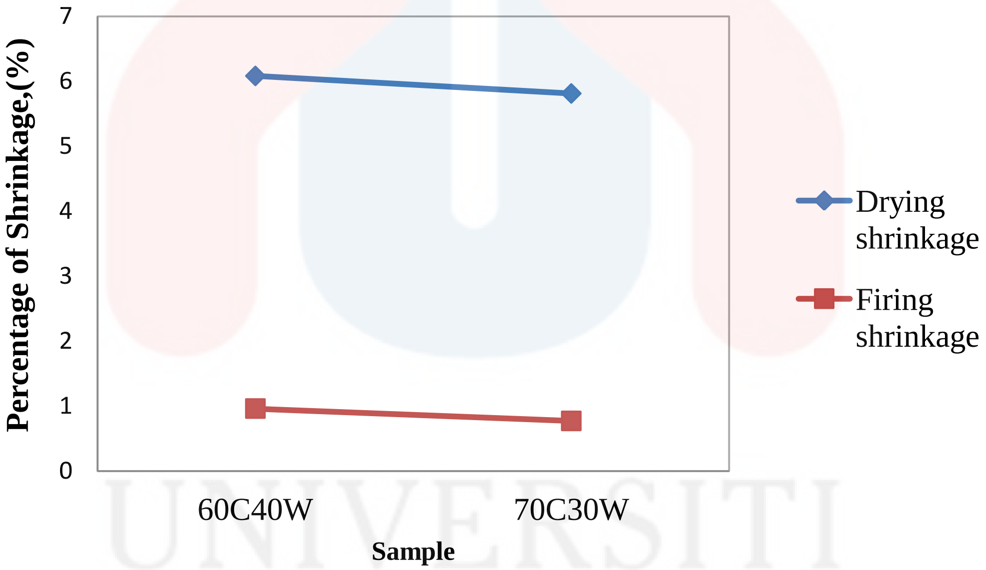

Figure 4.8 Comparison of drying and firing linear shrinkage between 60C40W and 70C30W

From Figure 4.8, 60C40W was seen to have higher percentage of drying and firing shrinkage compare to 70C30W. Shrinkage was closely correlated with the composition of water present in the clay slip. Higher composition of water in clay slip will rapidly increase the rate of shrinkage. The grater the water composition, the extensive the shrinkage process (Callister & Rethwisch, 2011). During drying

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process of the sample, large amount of water was evaporated which leave the sample smaller than its actual size. Sintering process also resulted in loss of water composition in sample but in small amount.

Percentage of shrinkage also affected from the percentage of porosity of the sample. When the clay sample was sintered, densification was undergone which eliminated the pores, thus, high percentage of pores have high percentage of shrinkage (Nawi & Badarulzaman, 2015). Besides from the shrinkage process that affected by the composition of water, sample warpage and shape distortion which showed in Figure 4.9 were also resulted by higher composition of water. This occurred because of the rapid shrinkage of the sample due to high speed rate of water absorption of clay slip.

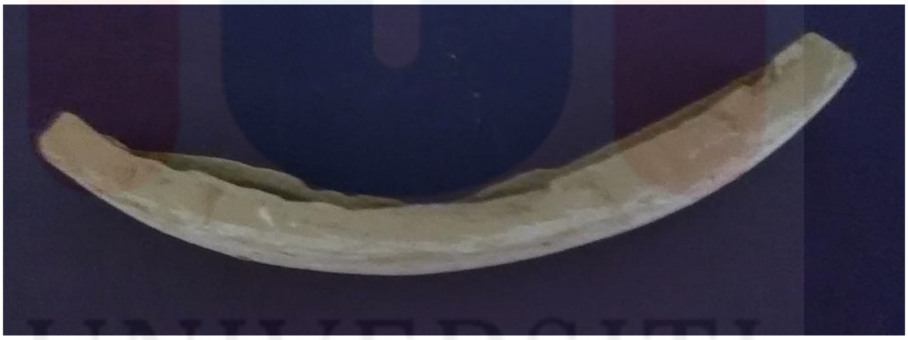

Figure 4.9 Warpage of 50C50W

In pottery making, potters must need the green body to have low percentage of shrinkage to avoid variation in size of pottery been made. For example the problems that rise due to non-equilibrium of shrinkage process, the Mambong clay lid’s size and its round bottom jar mouth’s size was not matched. The Mambong pottery and its lid are shown in Figure 4.10.

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The final length of fired 70C30W and 60C40W except 50C50W and 80C20W were showed in Figure 4.11 and 4.12 respectively. The samples had undergone drying and firing shrinkage, thus, shrunk from its initial length at 15 cm. The drying and firing shrinkage of 50C50W was not done due to the dimensional distortion occurrence because of higher composition of water than in 60C40W and 70C30W.

Figure 4.10 Mambong pottery and its lid

Figure 4.11 Fired 70C30W final length

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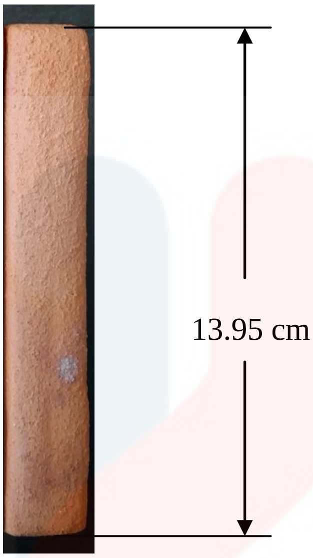

Figure 4.12 Fired 60C40W final length

Finding the percentage of shrinkage was very crucial as it is very important property of clay especially for the structural clay product because it involved with the loss of original dimension of the clay product (Emiroglu et al, 2015). 70C30W have low percentage of both drying and firing linear shrinkage compared to 60C40W due to low composition of water present in clay slip.

4.3.2 Density and porosity

The mass of sample was taken by using density kit in three conditions which are mass in air (dry mass), mass of sample in water and mass of water-saturated sample. With value of masses obtain in those three conditions, the porosity of sample also can be calculated. Both density and porosity was tightly related to each other. Increased in density will resulted in decreased in porosity (Nawi & Badarulzaman, 2015).

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The results of density of both samples are shown in Table 4.5. The comparisons of density between 60C40W and 70C30W were presented in Figure 4.13. The value of density and porosity of 50C50W and 80C20W cannot be done because the compositions are not suitable for slip casting technique which resulting in sample failures like warpage, crack and break.

Table 4.5 Density comparison between 60C40W and 70C30W

Sample	Density, kg/cm^3			
	Sample 1	Sample 2	Sample3	Average
60C40W	1.50	1.46	1.45	1.47
70C30W	1.44	1.49	1.45	1.46

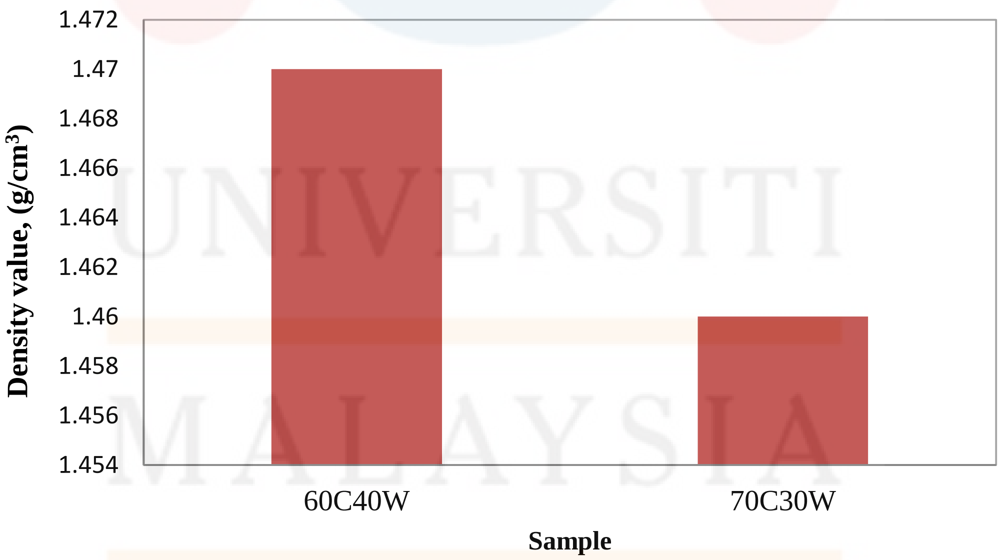

Figure 4.13 Comparison of density between 60C40W and 70C30W

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From Figure 4.13, 60C40W tend to have higher density compared to 70C30W sample. As showed in Table 4.6, the density of 60C40W was 1.472 g/cm^3 while 70C30W was at 1.461 g/cm^3. The density was related to the composition of clay present in sample. High composition of clay should produce sample that was denser than the sample that have low composition of clay.

There were some errors had been occurred during conducting the density test like calibration error of the density kit. The readings of mass of samples were taken before the kit was completely calibrated. As for the water-saturated sample, its mass was taken before the sample was fully saturated, thus, the air bubbles stilled present in the sample which can affected the readings of sample.

The density kit was also very sensitive to surrounding. Present of wind and any strong movement near the density kit can affected the reading of sample. All the errors present can lead to miscalculation in the density of the sample. The readings in calculating the density of sample were used to calculate the porosity of the sample. The results of porosity for both samples are shown in Table 4.6.

Table 4.6 Percentage of porosity comparison between of 60C40W and 70C30W

Sample	Porosity, %			
	Sample 1	Sample 2	Sample3	Average
60C40W	33.30	35.50	40.20	36.30
70C30W	36.20	35.60	35.60	35.80

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Based on Table 4.6, the percentage of porosity of 60C40W was 36.30% while 70C30W showed slightly lower than 60C40W at 35.80%. The comparison of the percentage of porosity was showed in Figure 4.14.

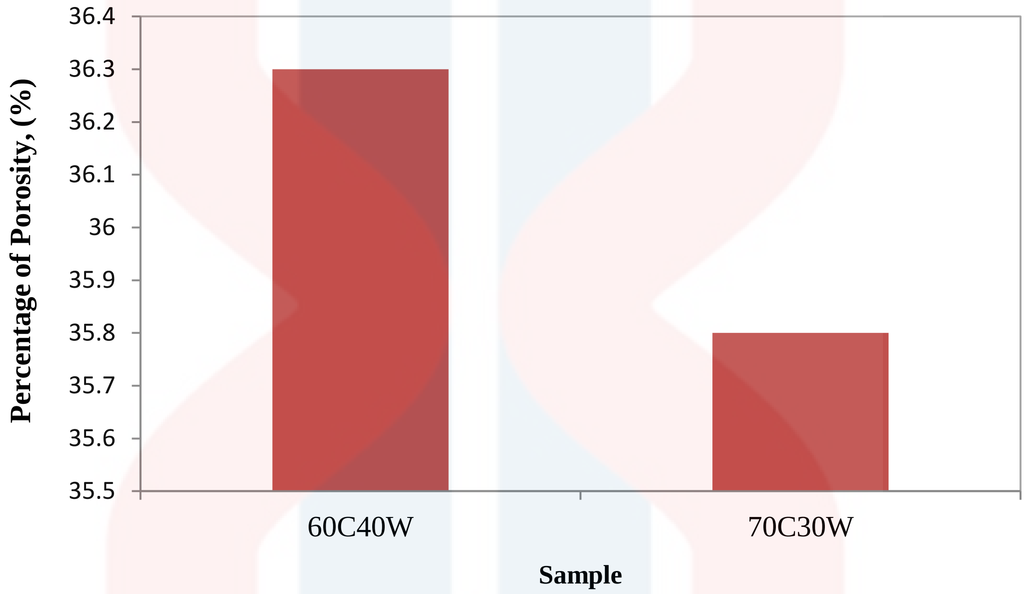

Figure 4.14 Comparison of percentage of porosity between 60C40W and 70C30W

According to Nawi and Badarulzaman (2015), clay with higher percentage of firing shrinkage have the higher percentage of porosity due to the densification occurred during the sintering process. In this test, 60C40W had higher percentage of porosity compared to 70C30W which was equivalent with the result percentage of firing shrinkage of 60C40W and 70C30W showed in Table 4.4.

The density of 60C40W showed higher value than 70C30W. The density of sample should directly proportional with the composition of clay present in the clay slip. As for the percentage of porosity, 60C40W showed higher percentage than 70C30W where it should be inversed with the value of density. There were several errors which occurred during the test that lead to miscalculation in density and percentage of porosity of samples.

4.3.3 Modulus of rupture (MOR)

Standard EN 14411: 2012 Ceramic Tiles. Definitions, Classification, Characteristics, Evaluation of Conformity and Marking define modulus of rupture (MOR) which also termed as bending strength as a derived from the magnitude breaking strength by a mathematical formula (breaking strength divided by the square of the minimum thickness at the rupture cross-section). The results of MOR test of 60C40W and 70C30W were presented in Table 4.7.

Table 4.7 Bending modulus and MOR comparison between of 60C40W and 70C30W

Sample	Bending Modulus, N/mm^2	Modulus of Rupture (MOR), N/mm^2
60C40W	9390.99	22.96
70C30W	15678.53	36.91

From Table 4.7, the bending modulus of 60C40W was 9390.99 N/mm^2 which lower than 70C30W that have 15678.53 N/mm^2. For modulus of rupture of 60C40W was 22.96 N/mm^2 which lower than 70C30W that have 36.91 N/mm^2. Modulus of rupture was associated with the bending modulus. Higher bending strength gave higher modulus of rupture. The comparison of modulus of rupture between 60C40W and 70C30W was presented in Figure 4.15.

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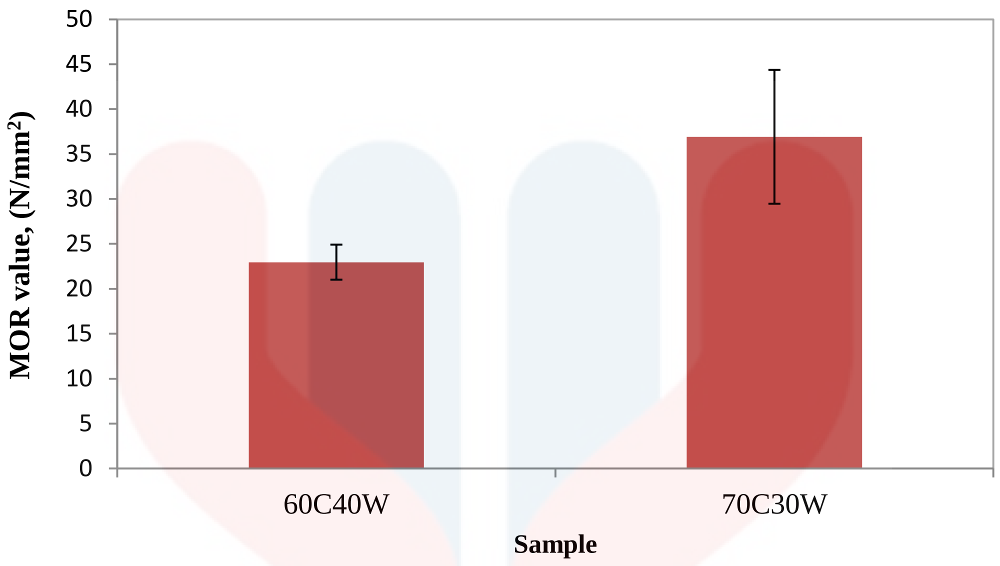

Figure 4.15 Comparison of modulus of rupture between 60C40W and 70C30W

From Figure 4.15, the modulus of rupture showed higher for 70C30W compared to 60C40W sample. Modulus of rupture was affected by the composition of the clay in clay slip. Higher composition of clay was present in 70C30W than 60C40W. Higher composition of clay made the sample denser and less porosity than the sample with low composition of clay.

Density had major influenced in the modulus of rupture which higher density tend to have higher value of modulus of rupture (Braganca & Bergman, 2004). Porosity was also deleterious to the flexural strength or the modulus of rupture by two reasons which were the pores will reduced the cross-sectional area across which load was applied and it acted as stress concentrators (Callister & Rethwisch, 2011).

Higher composition of clay in clay slip gave higher density of sample that also have low porosity present in sample, thus, increase the modulus of rupture of clay sample. The 70C30W had higher modulus of rupture and bending modulus than 60C40W.

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CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research was conducted to characterize the physical and mechanical properties of Mambong clay samples with different composition of clay and water. The samples were labelled as 50C50W, 60C40W, 70C30W and 80C20W following its composition of clay and water. The characterization done was categorized into two which were the raw material characterization and fired sample characterization.

For raw material characterization, the particle size of clay powder was controlled to below 425μm. In specific gravity (S.G) of the clay slip test, the sample appeared to be the best composition to be used for slip casting method was 70C30W sample. The S.G. of clay slip of 70C30W was 1.78 while other 50C50W and 60C40W were too slurries with S.G. of clay slip at 1.42 and 1.54 respectively while 80C20W formed bulk of clay which not suitable for slip casting method.

In casting test, the shortest time taken of sample removal recorded was on 70C30W at one hour compared to 50C50W and 60C40W. The time taken to remove the sample from mould was depended on the composition of water in clay slip. Higher compositions of water have the longest time taken of sample removal like 50C50W. Shortest time taken was favoured because it can increased the productivity of the Mambong pottery, thus, 70C30W was the most preferred composition.

For fired sample characterization, the colour of sample changed from light brown to reddish brown colour due to present of red iron oxide (Said et al, 2011). In measuring percentage of drying and firing linear shrinkage, 70C30W showed the

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lowest percentage compared to 60C40W at 5.81% and 0.77% respectively. Mambong clay also showed lowest percentage of drying and firing shrinkage compared to Sayong clay which have 6% and 10% respectively when compared to 70C30W.

In density and porosity test, 70C30W appeared to have low density and low percentage of porosity than 60C40W where the density value should vice versa. This might due to some errors that had occurred during the testing such as calibration error, technique in conducting the test, and other factor like surrounding where the test was conducted, for examples, present of wind and strong movement gave effect to the reading scale of the density kit.

In MOR test, 70C30W showed higher MOR and bending modulus at 36.91 N/mm^2 and 15678.53 N/mm^2 respectively than 60C40W at 22.96 N/mm^2 and 9390.99 N/mm^2 respectively. High MOR or flexural strength property was affected by the density and percentage of porosity of the samples which related with the composition of clay present in the clay slip.

5.2 Recommendation

More research and study on Mambong clay and pottery should be done in order to improve the properties of the pottery, thus, boost the quality of Mambong pottery. The research should cover the parameters in processing and testing to observe the properties of the pottery. The properties of Mambong pottery also should be compared with other pottery in Malaysia like Sayong, Terenang and Sarawak pottery.

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There are more parameters in processing Mmbong pottery that need to be further study to obtained optimum properties and quality of pottery. Some of the parameters are Mambong clay particle size, the sintering temperature and its heating rate and water absorption properties which is very important as Mambong pottery was use to make product like water storage. Thermal shock also can be studied as most of the Mambong potteries are made as kitchen ware like steam pot.

Physical and mechanical testing need to be done in order to observed the behaviour of the Mambong pottery when subjected to external element such as force, load, water and heat. Physical testing that should be study including water absorption and percentage of drying and firing linear and volumetric shrinkage with different parameters. For mechanical testing, it should including impact test.

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APPENDICES

APPENDIX A: Percentage of linear shrinkage

Table A.1 Measurement of length of 60C40W before firing

Dimension \ Size	Reading 1	Reading 2	Average
Length	141.14	140.61	140.88

Table A.2 Measurement of length of 60C40W after firing

Dimension \ Size	Reading 1	Reading 2	Average
Length	139.27	139.78	139.53

Table A.3 Measurement of length of 70C30W before firing

Dimension \ Size	Reading 1	Reading 2	Average
Length	141.44	141.41	141.29

Table A.4 Measurement of length of 70C30W after firing

Dimension \ Size	Reading 1	Reading 2	Average
Length	140.86	140.36	140.20

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APPENDIX B: Density and porosity

Table B.1 Dry mass, suspended mass and water-saturated mass of 60C40W

Mass, g \ Sample	Sample 1	Sample 2	Sample 3
M_d	1.034	0.661	0.348
M_s	0.575	0.370	0.205
M_w	1.263	0.821	0.444

Table B.2 Dry mass, suspended mass and water-saturated mass of 70C30W

Mass, g \ Sample	Sample 1	Sample 2	Sample 3
M_d	1.310	0.927	0.458
M_s	0.712	0.528	0.255
M_w	1.650	1.148	0.570

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