Faculty of Manufacturing Engineering

EFFECT OF GROG ADDITION ON LOCAL CLAY CERAMIC PROPERTIES USING EXTRUSION METHOD

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DECLARATION

I declare that this thesis entitled "Effect of Grog Addition on Local Clay Ceramic Properties Using Extrusion Method" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Author's Name : Hazlinda binti Kamarudin

Date : 15 August 2014

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award Master of Manufacturing Engineering (Industrial Engineering).

Signature :.....

Supervisor Name : Assoc. Prof. Dr. Mohd Warikh bin Abd Rashid

Date :14.8.2014

DEDICATION

To my beloved husband, Edynoor bin Osman, my lovely sons Muhammad Daniel Haikal, Muhammad Daffy Danish also my cutest daughter, Nourish Zara Aleeysa. Their source of my inspiration and strength in pursuit of excellence. To all my family members ecspecially to my father, Kamarudin bin Ahmad also my mother-in-law, Surati binti Sarip and father-in-law, Osman bin Sirjan who always pray for us happiness. To my late mother, Rosnah binti Mamat, who always be in my heart. Thanks for all support and encouraged towards the end of this journey.

ABSTRACT

Non-plastic material such as grog is widely used in brick, roofing and floor tile making. Grog is produced from ceramic waste that was recycling to be use as an additive in ceramic body system. With regards to the case in Ceramic Workshop, Kolej Kemahiran Tinggi MARA Masjid Tanah, the ceramic waste after bisque firing process may arise due to daily activities or production. Hence this study was carried out to determine the effect of grog to the local clay ceramic properties. Local clay original deposited from Sungai Petai village, Alor Gajah Melaka incorporated with grog has been fabricated by using extrusion method and sintered at temperature 1200 °C. Since the grog is non-plastic material, the amount and particle size was optimized. Two parameter of grog that is percentage of addition varied from 0%, 10%, 20% and particle size from coarser (2000 μm) to finer (200 μm) was studied. From the findings, it is shown that amount of grog addition and its particle size has give the impact towards local clay ceramic properties such as plasticity, water absorption, apparent porosity, shrinkage and compressive strength. From the plasticity testing, it is found that 0% grog has developed plasticity at lower water content. Deformability ratio and proportionality factor was decreased with the increasing amount of grog and particle size makes it less plasticity. The physical and mechanical properties of local clay fired sample have been successfully studied. In lieu of result findings, it is shown that 10% grog addition with finer particle size, 200 μm give the lowest percentage of drying and total shrinkage with 3.75% and 6.28% respectively, lowest percentage of water absorption, 8.68% and apparent porosity, 18% compared to the others. In term of mechanical properties, 10% grog addition with finer particle size has shown highest compressive strength value, 53.67 N/mm^2. This finding was supported by microstructure analysis to examine the pores, interfacial bonding, present of void and particle distribution that lead sample failure. The addition of grog in local clay not only can reduce the shrinkage but also improve the physical and mechanical properties of ceramic bodies. On the other hand, it also can benefit the waste and reduce the raw material cost if grog and local clay can be utilized especially in ceramic manufacturing.

ABSTRAK

Bahan bukan plastik seperti grog telah digunakan secara meluas dalam pembuatan bata refraktori, bumbung, dan jubin lantai. Grog dihasilkan daripada bahan buangan seramik yang telah diproses semula untuk digunakan sebagai bahan tambah dalam sistem jasad seramik. Berlandaskan kepada kes di Bengkel Seramik, Kolej Kemahiran Tinggi MARA Masjid Tanah, bahan buangan seramik selepas proses pembakaran biskut meningkat disebabkan oleh aktiviti atau produksi harian. Oleh itu, kajian ini telah dijalankan untuk menentukan kesan grog terhadap sifat seramik tanah liat tempatan. Tanah liat tempatan ini adalah mendapan asal daripada Kampung Sungai Petai, Alor Gajah Melaka telah dicampurkan dengan grog dan sampel dihasilkan melalui kaedah penyemperitan seterusnya sampel telah disinter pada suhu 1200 °C. Memandangkan grog adalah bahan bukan plastik, jumlah dan saiz partikel akan dioptimakan. Dua parameter grog iaitu peratus penambahan telah dipelbagaikan daripada 0%, 10%, 20% dan saiz partikel dari kasar (2000 μm) ke halus (200μm) telah dikaji. Daripada apa yang telah diperolehi, ia menunjukkan jumlah penambahan grog dan saiz partikelnya memberikan kesan terhadap sifat seramik tanah liat tempatan seperti keplastikkan, penyerapan air, keliangan nyata, pengecutan dan kekuatan mampatan. Daripada ujian keplastikkan, didapati 0% grog telah mengembangkaan sifat keplastikkan pada kandungan air yang rendah. Nisbah ubahbentuk dan faktor kelangsungan menurun dengan peningkatan penambahan grog. Manakala sifat fisikal dan mekanikal sampel bakar tanah liat tempatan juga telah berjaya dikaji. Berasaskan keputusan, ia menunjukkan 10% penambahan grog dengan saiz partikel yang halus, 200μm telah memberikan peratusan pengeringan dan jumlah keseluruhan pengecutan yang rendah dengan 3.75% dan 6.28%, peratus kadar penyerapan air yang rendah, 8.68% dan peratus keliangan nyata, 18% berbanding dengan yang lain. Dari segi sifat mekanikal, 10% penambahan grog dengan saiz halus telah menunjukkan nilai kekuatan mampatan yang tinggi iaitu 53.67 N/mm^2. Keputusan ini telah disokong oleh analisis mikrostruktur untuk memeriksa ikatan antaramuka, kehadiran liang, retak dan penyerakkan partikel yang boleh mengakibatkan kegagalan sampel. Penambahan grog ini bukan sahaja dapat mengurangkan pengecutan tetapi juga memperbaiki sifat fisikal dan mekanikal jasad seramik. Dengan kata lain, ia juga dapat memanfaatkan bahan buangan dan mengurangkan kos bahan mentah jika grog dan tanah liat tempatan ini dapat digunakan terutamanya dalam pembuatan seramik.

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LIST OF ABBREVIATIONS AND SYMBOLS

σ	-	Compressive strength
F_f	-	Load of the specimen
γ	-	Gamma
β	-	Beta
α	-	Alpha
μ	-	Micrometer
g	-	Gram
ρw	-	Density of water
l_o	-	Initial length
l_f	-	Final length
°C	-	Degree Celcius
kN	-	kiloNewton

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CHAPTER 1

INTRODUCTION

1.1 Background of study

The ceramic product manufacturing involves the use of clays that are naturally plastic and non-plastic materials. Clay is used as ceramic material in many industrial fields such as building, construction, sanitary ware, tableware and pottery. Their applications are strongly dependent upon their chemical composition, structure, plasticity, physical and mechanical characteristics. Clay is minerals that consist of fine particle hydrous aluminium silicates which develop its plasticity when mixed with water. The high content of these minerals that exists in some clays, makes the process to fabricated the product become difficult because the large amout of water added. Thus for the high plasticity clay it needed to add non-plastic material to improve the process condition. Clay performs two important functions in ceramic bodies. Firstly it is show the higher workability when load is applied, maintain their shape also promote strength during drying and firing. Secondly they fuse over a temperature range, depending on composition to become dense and strong without losing their shape at higher temperature. Most traditional ceramic formulations are based on the use of natural mineral materials which are inexpensive and readily available such as local clay.

Silicate materials such as silica (SiO_2) are basic raw materials for much of the ceramic industry. SiO_2 is a major ingredient in glass, glazes, enamels, refractories, abrasives and whiteware composition. There is a variety of mineral forms in which silica occurs, but the most important as raw material is quartz. Together with quartz (filler), the triaxial composition

consists of the other two components that are clay (main) and feldspar (flux). The major consideration in this study is to explore the potential of grog to be used in ceramic bodies replaced the function of silica as filler, incorporated with local clay materials. Grog has been considered as replacements for conventional ceramic raw material that are becoming scarce and will be eventually exhausted. It is a non-plastic material formed by crushing ceramic waste into smaller size. The use of grog in fired clay brick and red ceramic has been established in many years. In related to fire clay brick application, compressive strength and water absorption are the most priority properties because it indicated the ability to resist face fracture (Karaman et al. 2006). Rahman (2012) stated that the other properties of fire clay needs to consider are bulk density, true density, cold crushing strength, shrinkage and thermal conductivity, supported by Kadir and Sarani (2012).

The critical factors affecting forming and firing processes are the material composition and sample preparation. In manufacturing, there are many types of forming process that can produces ceramic product such as casting, pressing and plastic forming. For plastic forming such as extrusion, the process involves to extrude a stiff plastic mix through a die orifice, and force into a nearly constant cross section of die. Extrusion process have few advantages compared to the others method such as it is continuous process, simple construction of die, easy to control machine parameter, easy to handle and commonly used for brick, sewer pipe, hollow tile and etc.

1.2 Problem statement

The commonly ceramic defects such as cracking, warping and others failure might be happen due to firing stages, material handling or human error during decoration process. These types of defect lead to product reject because it cannot be repair and classify as a waste.

In Ceramic Workshop, Kolej Kemahiran Tinggi Mara Masjid Tanah for example, the volume of ceramic waste after bisque firing may be arise from daily activities or production. Therefore, with regards to this phenomenon, this waste was recycling to produce grog that can be use as an additive in ceramic body formulation. The main constituents of nature clay are Alumina (Al_2O_3) and Silica (SiO_2). These systems are normally based on kaolinitic clays which generally present substantial shrinkage when fired. The addition of grog into clay sample will be able to reduce shrinkage and facilitates the drying stages whereas it promotes sintering and bonding during firing (Kirabira, 2003). It is supported by Vieira and Monteiro (2007) that the grog reduces the risk of dimensional defects. Higher and uneven shrinkage could lead to product warping and this must be avoided to achieve good quality of ceramic product.

This project was carried out to study the effect of grog on local clay ceramic properties. In lieu of result findings, it could establish the percentage of grog and it effect to the compressive strength, apparent porosity, water absorption and shrinkage has to be investigated. The contribution from the study is raw material cost can be reduced if the grog and local clay can be fully utilized as an alternative to the commercial non clay and clay material. Hence the low cost of ceramic structural product can be developed in the future with regards to the parameter study. Also, it can minimize the production waste of ceramic product that may harmful to the environment. Furthermore the use of local clay could be beneficial to use as raw material in clay brick or tile production instead of use as a souvenir or light duty application.

1.3 Objectives of study

i. To fabricate ceramic bodies with grog addition by using extrusion method.

ii. To analyzes the effect of percentage grog addition and particle size onto physical and mechanical properties of fired ceramic bodies.

1.4 Scope of study

In this study, the sample was developed using the local clay – Sungai Petai Village, Alor Gajah origin as the main raw material and grog as an additive. Material characterization has been carried out to all materials used in this project. Material composition of ceramic bodies comprises different percentage of grog in the range of 0%, 10% and 20% and different particles size. This material composition was used to form the plastic clay and proceed for plasticity test. Grog that was used in this project is ceramic waste type of calcined stoneware body that was reprocessing through crushing process. While the particle size of grog was used are 2000 μm (coarser) and 200 μm (finer). Then the sample was produced by using extrusion method to get an extruded clay body and sintered at 1200 °C. The physical and mechanical properties were investigated in response to compressive strength, apparent porosity, water absorption and shrinkage. To support the findings, microstructure analysis has been carried out to examine the microstructure of the fired sample in term of porosity, interfacial bonding, particle distribution, void and etc. The activity planning use for this study as presented in Gantt chart at Appendix A. About 125 samples was produced in this project with refer to the parameter study as represent in the Chapter 3. Table 1.1 shows the sample identity that used in this project. The detail about the data as presented in APPENDIX B to APPENDIX F.

Table 1.1 The identity of samples that has been used in this projects.

Sample identity	Description
100LC	0% grog (No grog)
10F	10% grog (finer particle size)
10C	10% grog (coarser particle size)
20F	20% grog (finer particle size)
20C	20% grog (coarser particle size)

In general, this ceramic sample are processed through three main stages before proceed to testing and evaluation; raw material preparation (local clay and grog), consolidation to compact through extrusion method and densification by sintering process. These three stages contribute the successful results to study the effect of grog addition on local clay ceramic properties.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Soil can be separated into three categories which are cohesion, cohesiveless and organic soil. Cohesive soil is characterized by very small particle and tends closer together, which is belongs to particularly clay (Sa'adon, 2009). Clay plays an important role in soil behaviour. Soils may be classified based on clay clay mineralogy which is below 30 - 35% clay; clay particles are dispersed in a matrix formed by the coarse particles. Above 30 - 35% clay, coarse particles are dispersed in a continuous clay matrix. Properties are determined by the clay mineralogy. These soils are known as clayey soils.

Many researchers studied the potential of their local clay to be use in variety of application. Saa'don (2009) studied the properties of Pekan Soft clay for construction, Jock et al. (2013) studied the Nigerian Ozanagogo clay deposit used for refractories and the potential of clay deposited from Tunisia have been studied by Baccour et al. (2008). Clay is rich with Kaolinite and Ahmed et al. (2009) reported that the export production of clay rich Kaolinite is greater than Japan, Taiwan and Phillipines.

There are two main raw material type used for conventional ceramic which is clay and non clay. Clay confers plasticity thus greater workability, while non clay reduces the shrinkage and prevent the fissuration upon heat treatment. Non-clay is important in the formation of final microstructure of ceramics (Gorea and Benea, 2002).

2.2 Location of local clay

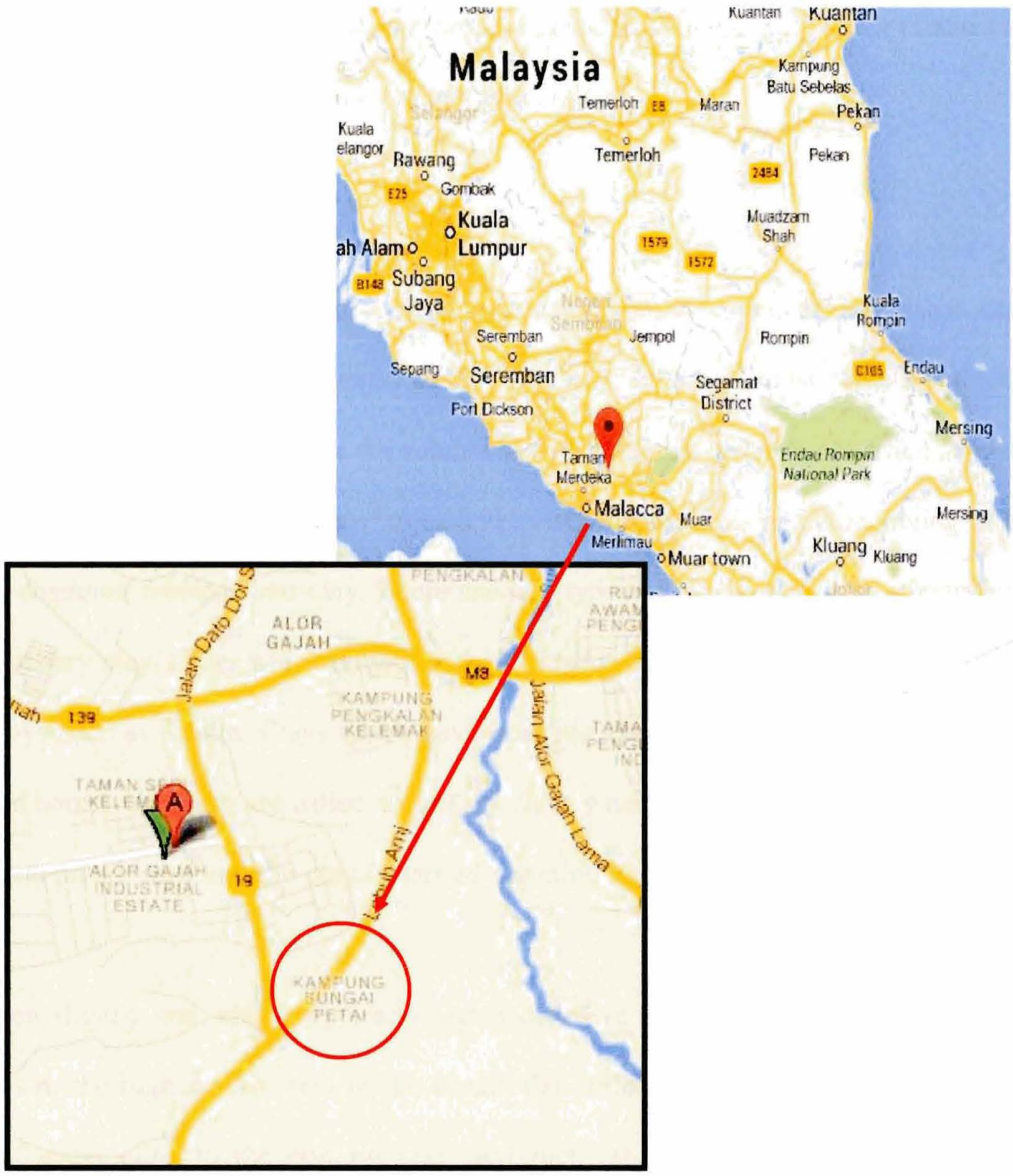

Figure 2.1 The location of Sungai Petai Village, Alor Gajah.

(http://www.satellitecitymaps.com/asia-map/malaysia-map/state-of-malacca-map/)

The local clay is originated deposit at Sungai Petai Village, near Alor Gajah town as presented in Figure 2.1. Sungai Petai Village is one of thirty one sub-districts in Alor Gajah, Malacca. The potential clay in Sungai Petai Village was published can be used in the ceramic

product making such as key chain, flower and other souvenier item as developed by Bendang Studio, Alor Gajah. The clay has presented properties such as high plasticity, rigid and hard body after firing that suitable in ceramic product processing.

2.3 Types of Clay

The formation of clay from rock is a most common event, taking place daily everywhere in the world. The weathered surface of the granite will most probably show a rough surface with many holes, where the soluble feldspar crystals have been washed away by rain, whereas the less soluble crystals of mica and quartz remain. This is the beginning of the process of changing feldspar into clay. There are two types of clay which is i) primary clay and ii) secondary clay. Clays which remain at their location of their parent rock are known as primary clays such as Kaolin. Clays which have been removed from their place of origin and have settled somewhere else are called secondary clays where rain washes the clay out from the site of its parent rock and the clay is carried downhill by rivers and streams such as Ball Clay.

When slightly wet, clay is typically highly cohesive and it sticks together very well. This relates to the high surface area of the broad, flat surfaces of the mineral grains. Small amounts of water cling to the clay particles and each other, producing a high degree of intergranular cohesion.

2.3.1 Ball clay

Ball clay is a fine-grained highly plastic, mainly kaolinitic, sedimentary clay, the higher grades of which fire to a white or near white colour in an oxidising atmosphere. It consist of varying proportions of kaolinite, mica and quartz, with small amounts of organic