UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CARBON FILLED GLASS CERAMIC: FROM WASTE TO WEALTH

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The member of the supervisory is as follow:

……

(Dr. Zaleha Bt Mustafa)

ABSTRAK

Kajian ini dijalankan untuk mengkaji kesan kandungan karbon yang dipenuhi seramik kaca: dari sisa kepada bahan yang berguna untuk menghasilkan jubin yang lebih poros dan ringan. Dalam kajian ini, sifat fizikal, mekanikal dan haba dikaji dengan kandungan karbon yang berbeza daripada 6 juzuk kumpulan muatan, iaitu 85:0:15, 84:1:15, 80:5:15, 75:10:15, 65:20:15 dan 55:30:15 (SLS kaca: karbon: tanah liat). Campuran serbuk SLS kaca, karbon dan bola tanah liat telah ditekan menggunakan mendesak ekapaksi dan disinter pada 850 ° C dengan kadar pemanasan dan penyejukan selama 2 °C/min dan 1 jam masa rendaman. Peratusan keliangan, serapan air dan ketumpatan pukal diukur menggunakan ASTM C373. Sifat kekerasan telah ditentukan mengikut ASTM E384 dan dilakukan dengan menggunakan pelet silinder berukuran 13 mm. Di samping itu, kekuatan lenturan telah ditentukan mengikut ASTM C1161 dengan ketebalan 5 mm. Sampel yang berbentuk segi empat tepat dengan ukuran 65 mm x 15 mm x 5 mm dihasilkan untuk menguji kekuatan lenturan dan sifat haba. Pengembangan pekali haba dilakukan mengikut ASTM E228 dan diukur menggunakan dilatometer (DIL 402 C, Netzsch, Jerman). Fasa dan analisis morfologi masing-masing telah dijalankan menggunakan X-Ray Diffractometer (XRD) dan Mikroskop Imbasan Elektron (SEM). Analisis fizikal menunjukkan bahawa dengan peningkatan kandungan karbon 0-30 wt.%, berlakunya peningkatan dalam penyerapan keliangan dan air. Sifat kekerasan berkurangan dan CTE meningkat dengan peningkatan kandungan karbon. Morfologi menunjukkan liang meningkat dari segi saiz dan bilangan dengan peningkatan kandungan karbon. Analisis fasa mendedahkan kehadiran fasa kristal cristobalite dan silikon dioksida dalam sampel.

ABSTRACT

This investigation is carried out to study effect of carbon filled glass ceramic: from waste to wealth in order to produce more porous and lightweight tiles. In this study, physical, mechanical, and thermal properties were studied with six different carbon contents which are 85:0:15, 84:1:15, 80:5:15, 75:10:15, 65:20:15, and 55:30:15 (SLS glass: carbon: ball clay). The powder mixtures of SLS glass, carbon and ball clay was pressed using uniaxial pressing and sintered at 850°C with heating and cooling rate of 2 °C/min and 1 hour soaking time. The apparent porosity, water absorption, and bulk density were measured using ASTM C373. The Vickers microhardness test was determined according to ASTM E384 and carried out using cylindrical pellet with 13 mm dimension. In addition, flexural strength was determined according to the ASTM C1161 with thickness of 5 mm. Rectangular samples with dimension of 65 mm x 15 mm x 5 mm were produced in order to test the flexural strength and thermal properties. Thermal coefficient expansion it performed according to ASTM E228 and measured using dilatometer (DIL 402 C, Netzsch, Germany). The phase and morphology analysis were carried out using the X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) respectively. Physical analysis showed that with increase of carbon content from 0 to 30 wt.%, increased the porosity and water absorption. Hardness properties decreases and CTE increased with increase of carbon content. Morphology shows the present of pores increase in size and number with increase of carbon content. The phase analysis revealed the present of cristobalite and silicon dioxide crystalline phases in the samples.

DEDICATION

I dedicate this thesis to my parents for their love and support. I hope this achievement will complete the dream that you had for me all those many years ago when you chose to give me the best education you could. Not to mention, my all friend who have been very helpful to me all along.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

SLS	-	Soda lime silicate
SiO_2	-	Silicon dioxide
Na_2O	-	Sodium oxide
CaO	-	Calcium oxide
Wt.%	-	Weight percentage
GCM	-	Glass composite material
MSW	-	Municipal Solid Waste
K^+	-	Potassium ions
Na^+	-	Sodium ions
Ca^{2+}	-	Calcium ions
Al_2O_3	-	Aluminium oxide
C	-	Carbon
CO_2	-	Carbon dioxide
CO	-	Carbon monoxide
Cu	-	Copper
MgO	-	Magnesium oxide
ZnO	-	Zinc oxide
Li_2O	-	Lithium oxide
BS	-	Bottom slag

MOR	-	Modulus of rupture
IBM	-	International Business Machine
HDPE	-	High density polyethylene
PSA	-	Particle size analyser
Rpm	-	Revolution per minute
UTM	-	Universal Testing Machine
CTE	-	Coefficient of thermal expansion
ASTM	-	American Standard Testing Material
XRD	-	X-Ray Diffraction
SEM	-	Scanning electron microscope
GPa	-	Giga Pascal
MPa	-	Mega Pascal
Gm	-	Grams
H	-	Hours
Min	-	Minutes

CHAPTER 1
INTRODUCTION

1.1 Overview

Glass is an amorphous solid. It used in plenty of applications such as in packaging, tableware, housing and building, electronic, industry and etc. Glasses can be categorized as brittle and typically transparent. Nowadays, the amount of waste glass is increasing due to increase in glass based products. Most of the waste is dumped into landfill and contribute waste management and lead to environmental problems. One of the efforts to overcome this problem is through recycling. Glass waste can be recycling into another product, which at the same time not only can reduce the municipal waste but reduce the cost of the product as the price as new product can be process at lower temperature. The most common type of glass is soda lime silicate (SLS), compose around 60-75% of silicon dioxide (SiO_2), 12-18% of sodium oxide (Na_2O) and 5-12% of lime (CaO).

Charcoal is used in this project as fillers. The main elements in charcoal are carbon and hydrogen. There are also other element which consists of hydrogen compounds, sulphur, oxygen, and nitrogen. The special properties of charcoal is mainly has good thermal conductivity which has an ability to conduct heat. At the same time, carbon also being use as pores agent to produce porous product.

Previous study used similar waste from SLS glass with different filler such as coal fly ash, incinerator fly ash and steel fly ash in order to save and protect the environment. However, glass-ceramics obtained from industrial wastes have several desirable properties to fulfil many applications such as wall-covering panels, floors and roofs in industrial and public buildings, interior facing of containers for the chemical industry and as a road surfacing. GCM that produced from industrial waste is one of the low investments. Therefore, this study will focus on characterization of glass composite filled with carbon with effect of different filler loading.

1.2 Problem statement

The handling and management of the domestic municipal solid waste in most developing countries is fairly limited (Aguilar-Virgen *et al.,* 2010). The increasing in population contributed to the increasing production of waste daily. Thus, the need to utilize this waste is very important in order to meet the demand of source of material in the future. The failure to manage the domestic waste production brings a major impact towards the demanding of raw material and also to the financial of the citizen. In the states of the developing nations, the handling costs of the domestic waste involve almost half of the local government expenditures (Emmanuel *et al.,* 2013). Glass is one of the major contributors to the domestic waste as it is the raw material for much of the consumer products such as beverages packaging, household equipment and also in structural application. According to Wollongong City Council, in 2008, the second largest consumption of residential waste was found to be glass accounting to 37.5% composition by weight percentage of the 240 L residential recycling bin. In Malaysia, most of the wastes are being thrown away in the disposal land and this practice is no longer promising as the land is limiting due to increasing population of the nation (Manaf *et al.,* 2009). Thus, the need to bring awareness among people on recycling the waste materials are essential especially the glass.

Glass waste can be recycled in order to protect the environment as well as providing an opportunity to produce new material. According to Nour *et al.,* (2008), industrial

wastes and by products recycled is becoming a high demand by the ecological law to achieve a green environment without any hazard to the living human, organisms; animals and plants. The SLS glass is obtained from urban waste such as glass bottle and household glass container. Through recycling glass, the problem about environment and economical can be reduced. However, glass ceramic that obtained from industrial waste can be used in many applications such as wall covering panels, floors and roofs. Then, it also can be used in industrial and public buildings, interior facing of containers for the chemical industry and as road surfacing.

After that, technique that used to produce glass ceramic materials is traditional glass forming that beginning with melt the glass and then controlled by nucleation and crystallization heat treatment processes (Erol *et al.,* 2009). So, the addition of filler towards the recycled glass can increase the properties of the material in analytical manner. Therefore, the characteristics of recycled glass produced with the addition of the carbon can be analysed physically, mechanically and thermally.

1.3 Objectives

The main objectives of this project are:

1. The effect of the carbon content on the physical properties of the recycled glass composite

2. The effect of carbon content on mechanical properties of the recycled glass composite

3. The effect carbon content on the thermal properties of the glass composite

1.4 Project Scope

The scope of this study is to utilize the abundant waste of SLS glass and make it into useful glass ceramic products. The main raw material that used in this project is soda

lime silicate glass that acquired from waste glass like bottles and food containers. After that, the other material used is charcoal. It is very important in this project as filler. The ball clay also used in this project as a binder to the glass ceramic. The standard or reference sample consists of 85:00:15 wt% of SLS glass mixed with carbon and ball clay. In this project, ball clay acts as a fixed variable which is 15 wt%. The batch formulation with the addition of carbon was varied 1%, 5%, 10%, 20% and 30% of weight percentage of carbon and the remaining is from SLS glass. The loading was made in weight percentage of the samples and weighted as 100 gm. The samples were analysed in term of its physical, mechanical and thermal properties of the products.

The samples were shaped by using uniaxial pressing and sintered to allow the densification of the green body of the ceramics at temperature of 850 °C. The heating rate and soaking time that used are 2 °C min^{-1} and 1 hour, respectively.

The porosity, water absorption and bulk density were performed according to the American Society of Testing Material (ASTM) standards. The mechanical testing involved hardness and flexural strength in order to investigate the strength of the ceramic sample produced. The thermal properties test was done by using dilatometer (DIL 402 C, Netzsch, Germany) which is to investigate the change in sample size per degree change in temperature at a constant pressure. Morphological study that involved in this project is SEM.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Waste can be defined as unwanted or unusable materials by the human. As reported to the Basel Convention (2009), stated that wastes can be defined as substances or objects that are intended to be disposed including municipal solid waste (MSW), hazardous waste, waste water, radioactive waste, and others.

Rapid rise in municipal waste generation occurred, according to the urbanization and economic growth. In 2012, the World Bank projected state that municipal solid waste will grow from 1.3 billion tonnes in 2010 to 2.2 billion tonnes by 2025. Increasing in quantity and changing in composition leading to the municipal waste in many cities while the financial resources to manage waste remain flat. The solid waste composition that produced for the global is shown in Figure 2.1.

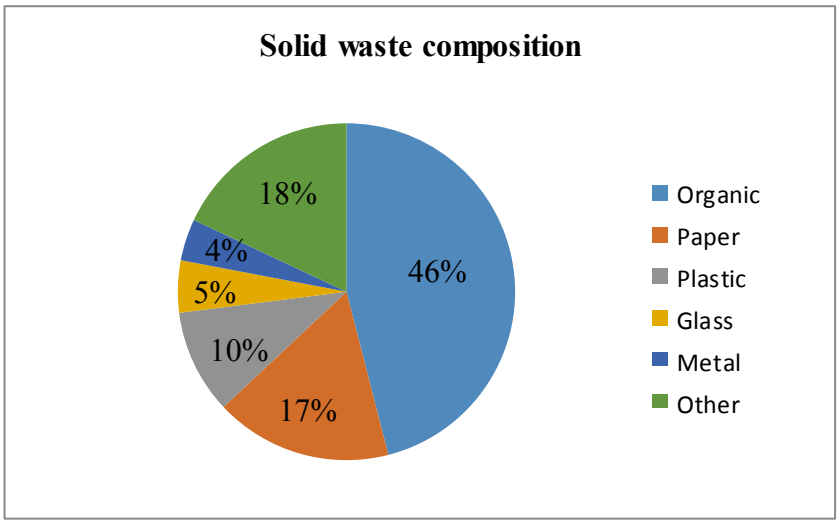

Figure 2.1: Solid waste composition (redrawn from "What a Waste: A Global Review of Solid Waste Management", 2012)

2.2 Recycling glass

Waste glass can be recycled in order to overcome the problems which involved the large amount of glass product with people nowadays. When recycle the glass, it provides several advantages such as can save energy as it needs lower energy to recycle glass than manufacturing a new one. Besides that, it will also reduce the emission as there are no by product produced. By recycling industrial waste, it can protect the environment and reduce consumption of glass as well as reported by Erol *et al.,* (2009).

Recycling glass provide several advantages such that the preservation of raw material sources such as sand, soda ash and limestone. The process also save more energy as it needs lower energy to recycle glass than manufacturing a new one. Instead, there is also no reduction of emission as there are no by product produced.

2.2.1 Soda lime silica (SLS) glass

SLS glass can be used in many applications such as windowpanes, and glass container for beverages, food, and agricultural. SLS is made up of silicate sand, which gives the glass its texture; it is known as the glass former or SiO_2 network former. Soda is used as a melting agent to lower the melting temperature of the silica and as a fining agent to homogenise the melting mixture and to eliminate bubbles. For soda-lime glass, it is not really expensive, reasonable hard, stable in chemically and extremely workable. Then, it is also very suitable for glass recycling because it has ability of being re-softened and re-softened and then re-melted for many times.