UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECT OF COLOURING AGENT ON THE CORROSION PROPERTIES OF GLASS COMPOSITE TILES

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

LIYANA BINTI MUHAMAD ALI

B050910157

910902-11-5134

FACULTY OF MANUFACTURING ENGINEERING

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Cop Rasmi:

DR. JARIAH BINTI MOHAMAD JUOI
Associate Professor
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Tarikh: 3/7/2013

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This report is submitted to the Faculty of Manufacturing engineering of UTeM as a partial fulfilment of requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) with Honours, the members of supervisory committee is as follow:

....

PM. DR. JARIAH BINTI MOHAMAD JUOI

(Principal Supervisor)

ABSTRACT

The purpose of this project is to study the effect of colouring agent on the corrosion properties of glass composite tiles. The raw material used is waste soda lime silicate glasses (SLSG) which are transparent and green coloured glass. The glass were milled and sieved to < 75 μm and mixed with ball clay that acts as the filler. Waste SLSG (transparent and green) is mixed with ball clay according to the optimum ratio of 90:10 wt. % for transparent GCM and 85:15 wt.% for green GCM. The mixture are then pressed using uniaxial die pressing and sintered at 850°C with 1 hour holding time. Water absorption, porosity, and density analyses of both GCM produced are analyzed through ASTM C373. Corrosion analyses are carried out using different types of aqueous solution which are low and high concentration of acid and alkali based on Malaysian Standard (Determination of chemical resistance). The main crystalline phase in both GCM identified using X-ray diffraction (XRD) analysis is quartz (SiO_2). Microstructure analysis conducted using scanning electron microscope (SEM) reveals the presence of quartz indicating that crystallise take place during sintering. The physical properties of GCM produced from transparent glass and green coloured glass are 0.06% porosity, 0.03% water absorption, 1.79 g/cm^3 of bulk density; and 0.03% porosity, 0.02% water absorption, 2.05 g/cm^3 of bulk density; respectively. Highest corrosion rate for both transparent and green coloured GCM is observed after been soaked for 5, 12 and 13 days is Lactic acid solution (high concentration acid). The corrosion rates after 13 days of soaking in the Lactic acid solution are 3.84 mpy for transparent GCM and 3.92 mpy for green coloured GCM.

ABSTRAK

Tujuan projek ini adalah untuk mengkaji kesan pewarna pada sifat-sifat kakisan jubin kaca komposit. Bahan mentah yang digunakan adalah sisa soda kapur silikat kaca (SLSG) iaitu kaca telus dan kaca berwarna hijau. Kaca telah hancurkan dan diayak <75 μm dan dicampurkan dengan bebola tanah liat yang bertindak sebagai pemangkin. Kaca SLSG (telus dan hijau) dicampurkan dengan bebola tanah liat mengikut nisbah optimum 90:10 wt. % untuk bahan komposit kaca telus dan 85:15 wt.% untuk bahan komposit kaca berwarna hijau. Pembentukan bahan campuran dijalankan menggunakan kaedah penekanan dan disinter pada suhu 850^oC selama 1 jam. Penyerapan air, keliangan, dan ketumpatan dijalankan untuk menganalisis kedua-dua bahan komposit kaca melalui ASTM C373. Analisis hakisan dijalankan dengan menggunakan asid dan alkali berkepekatan rendah dan tinggi berdasarkan Piawaian Malaysia (penentuan rintangan bahan kimia). Fasa utama dalam kedua-dua kristal GCM dikenal pasti menggunakan pembelauan sinar-X (XRD) analisis adalah kuarza (SiO_2). Analisis mikrostruktur dijalankan menggunakan mikroskop imbasan elektron (SEM) menunjukkan kuarza hadir dan membawa kenyataan yang ia berlaku semasa pensinteran. Ciri-ciri fizikal bahan komposit kaca yang dihasilkan daripada kaca telus dan kaca berwarna hijau adalah 0.06% keliangan, 0.03% penyerapan air, 1.79 g/cm3 ketumpatan pukal dan 0.03% keliangan, 0.02% penyerapan air, 2.05 g/cm3 ketumpatan pukal. Kadar hakisan tinggi untuk kedua-dua bahan komposit kaca telus dan kaca berwarna hijau di kenal pasti selepas direndam selama 5, 12 dan 13 hari adalah apabila di dalam larutan asid laktik (asid kepekatan yang tinggi). Kadar hakisan selepas 13 hari direndam dalam larutan asid laktik adalah 3.84 mil setahun untuk bahan komposit kaca telus dan 3.92 mil setahun untuk bahan komposit kaca berwarna hijau.

DEDICATION

Dedicated to my beloved parents, family and friends

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%	-	Percent
ºC	-	Degree Celsius
ρ	-	Density
μm	-	Micrometer
ASTM	-	American Society Testing Material
cm^3	-	Centimetre cube
EDX	-	Energy dispersive X-ray
g	-	Gram
GCM	-	Glass composite materials
GPa	-	Giga Pascal
h	-	Hour
HK	-	Knoop hardness
J	-	Joule
K	-	Kelvin
K_{IC}	-	Critical stress intensity factor
min	-	Minute

MPa	-	Mega Pascal
nm	-	Nanometre
SEM	-	Scanning electron microscope
SLSG	-	Soda lime silicate glass
T_g	-	Glass transition temperature
UV	-	Ultraviolet
wt. %	-	Weight percentage
XRD	-	X-ray diffraction

CHAPTER 1

INTRODUCTION

1.1 Background of study

Waste is an unavoidable by-product of most human activity. According to United Nations Economic and Social Commission for Asia and the Pacific Organization (2013), economic development and rising living standards in the Asian and Pacific Region have led to increases in the quantity and complexity of generated waste. There is a great concern regarding to the increasing amount of industrial wastes such as plastics, glasses, and grog (fired clays). The disposal of these wastes is one of the issues that have received a lot of attention and a high demand for the safety of the environment. One technique used to reduce such wastes is by recycling, which is not only benefits to the environment but also to the economy (Loryuenyong *et. al.* 2009). The success of glass recycling programs has resulted in more post-consumer glass than municipalities can use; there is also a post-industrial glass waste available. The development of alternate products that make use of both types of glass helps in many ways: by reducing landfill, by reducing the need for recycled glass storage, and by supporting the economic viability of recycling programs.

There are different kinds of wastes that have already been recycled in ceramic industry for example waste glasses, which are readily incorporated as an alternative ceramic raw material or as a fluxing agent in stoneware, tiles, bricks and concrete (Brown and Mackenzie *et. al.* 1982). However, among these, many thousands tones of glass are discarded, much in the form of non-returnable bottles and containers. Glass is an ideal material for recycling. The use of recycled glass in new container helps save of energy. It helps in brick and ceramic manufacture, and it conserves raw materials, reduces energy consumption, and the volume of waste sent to landfill (Turgut and Yahlizadec *et. al.* 2009).

The glasses and ceramics are consist of oxide, fluoride, silicate, borate, phosphate, and related compositions that make up common ceramic materials. These materials are electrically insulating and contain few free carriers, so that chemical attack on their surfaces is mainly by acid-base type of reactions rather than electrochemical corrosion involving redox reactions. Crystalline ceramics and non-crystalline glasses of similar composition often have quite different corrosion behaviour showing that structure at the atomic scale also plays a role. Interest in glass corrosion comes from the necessity of understanding stability of glass containers, sheet glass, and other glasses in the presence of aqueous solutions (White *et. al.* 1981). In general, the solutions are highly under saturated, may be strongly acidic or basic, and the concern is with times in the range of a few years. In contrast, the study on the dissolution (corrosion) of crystalline ceramics is relatively rare because in the environments in which most of these materials are use, attack by aqueous solutions is not a problem to the environment (White *et. al.* 1981).

1.2 Problem statement

Humans have always produced trash and have always disposed of it in some way, so solid waste management is not a new issue. What have changed are the types and amounts of waste produced, the methods of disposal, and the human values and perceptions of what should be done with it. Waste productions are always increasingly expected to be great, so, the major waste that should be in great concern is the production of glass waste. The production of glass composite materials made from recycling industrial waste can be classified as one of the known technology. According to literature, during the last decade the use of ecologic products has become an important aspect in the ceramic industry, in order to optimize and reduce the consumption of natural resources. Recycled glass can be obtained from several sources such as flat glass, glass bottle, lamps, television screens, etc. Moreover, its amorphous nature and composition (mainly silicon oxide, calcium oxide and sodium oxide) make it an excellent candidate for application in the ceramic industry as a flux agent and/or frits for glazes (Fraga *et. al.* 2011). Many researchers has paid a lot of attention to produce glass, glass ceramic, sintered ceramic materials made from waste glass to make those materials a better production to lead to environment. Waste glass obtained from construction wastes, industrial wastes, and medical wastes have desirable properties to fulfil in most applications such as tiles and roof for constructions, interior facing of containers for chemical/medical industry and as well as road surfacing. For that reason, the recycled glass has to possess compositional homogeneity and must be available in large quantities. The aim of the present work is to study corrosion properties of glass composite materials from recycled glass and ceramic waste as raw materials in the production of ceramic tiles.

Tiles are generally used for covering roofs, floors, walls, showers, or other objects such as tabletops. Alternatively, tile can sometimes refer to similar units made from lightweight materials, typically used for wall and ceiling applications. Tiles are often used to form wall and floor coverings, and can range from simple square tiles to complex mosaics. In many years, tiles are mostly applied in various applications that are highly exposed in different environment. The present study aims to investigate the corrosion properties of glass composite tile made from waste glass. The study involves chemical resistance of unglazed tiles against low concentration acid and alkali, and high concentration acid and alkali.

1.3 Objectives

There are several objectives of this project, which are:

1. To determine the physical properties of glass composite tile made from SLSG (transparent and green coloured) waste glass.

2. To characterize the microstructure and phases present in the produced glass composite samples.
3. To evaluate the corrosion properties of glass composite tile made by different SLSG waste (transparent and green coloured) glass.

1.4 Scope of study

In order to investigate the corrosion properties of glass composite tiles made from waste glass, the scope of the study is tailored to produce glass ceramic samples for structural application and chemical resistance with high corrosion resistance. The fabrication process was carried by common ceramic techniques (e.g. uniaxial pressing method). The study started by preparing recycles glass as raw materials that used in fabrication of glass ceramic samples. The glass powders were prepared by crushing bottles made from glass using hammer until they passed through a sieve of less than 75µm to obtain fine particles. The stage of process was followed by mixing the glass powder and ball clays with optimum ratio of 90:10 for transparent SLSG and 85:15 for green coloured SLSG. Ball clays act as fillers to improve the bonding properties between particles and help to obtain dense materials by sticking glass powders together during pressing method (Rozenstrauha *et. al.* 2006).

Forming process was then conducted to form the mixing glass powder into green ceramic article. Green was referred to the unfired ceramic. Preferably uniaxial die pressing is used with 3.5 gram of mixed powder per sample is pressed with 40 MPa (3.5 tons) in a cube shape with measurement 18 mm × 18 mm. The pressed article is then removed from the die and sintered in a furnace. The sintering temperature of this study would be the optimum sintering temperature based on previous investigation which is 850^{o}C. For each sintering, the duration of holding time was be one hour. At the end of this study, the sintered glass ceramic samples were then subjected to characterization, physical properties and corrosion properties analyses. The physical properties were analyzed using water absorption, porosity, and bulk density analyses, while the corrosion properties were analyzed through chemical test using weight loss technique. The microstructure analysis of the surface of the fabricated of glass ceramic were observed using the X-ray diffraction (XRD), scanning electron microscope (SEM) and energy dispersive X-ray (EDX). Results on the different waste glass utilized (transparent glass and green glass) were then compared in order to understand the effect of colouring agent on the glass composite corrosion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed the review related study on glass composite made from waste glass. The content is focusing on the properties and process preparing the glass composite produced from waste glass.

2.2 Waste

Waste is an unavoidable by-product of most human activity. Shirke (2009) referred waste as rubbish, trash, garbage, or junk is unwanted or unusable material. According to European councils' directive "Waste is any substance or object which the holder discards or intends or is required to discard." There are many source of waste such as residential, industrial, commercial, construction, municipal services, and institutional.

Solid waste can be defined as any solid or semi-solid substance or object resulting from human or animal activities, discarded as useless or unwanted (Shirke *et. al.* 2009). It is an extremely mixed mass of wastes, which may originate from household, commercial, industrial or agricultural activities; according to its contents (organic material, glass, metal, plastic paper etc); or