PRODUCTION OF FLY ASH-BASED GEOPOLYMER BRICKS THROUGH GEOLYMERIZATION PROCESS

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by

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LIST OF ABBREVIATIONS, SYMBOLS AND CHARACTERS

ASTM	-	American Society for Testing and Materials
Si	-	Silica
Al	-	Alumina
O	-	Oxygen
XRD	-	X-Ray Diffraction
SEM	-	Scanning Electron Microscopy
BS	-	British Standard
FBS	-	Face Brick Standard
FBX	-	Face Brick Extra
FBA	-	Face Brick Aesthetic
Fe	-	Iron
Ti	-	Titanium
P	-	Phosphorus
S	-	Sulfur
Mg	-	Magnesium
Cl	-	Chlorine
K	-	Potassium
Ca	-	Calcium
Zn	-	Zinc
Sr	-	Strontium
XRF	-	X-Ray Fluorescence
CaO	-	Calcium Oxide
NaOH	-	Sodium Hydroxide

Na_2SiO_3	-	Sodium Silicate
MPa	-	Megapascal
EPA	-	Environmental Protection Agency
TCLP	-	Toxicity Characteristic Leaching Procedure
CO_2	-	Carbon Dioxide
SiO_4	-	Silicate
AlO_4	-	Aluminates
OPC	-	Ordinary Portland Cement
3D	-	Three Dimensional
LTGS	-	Low Temperature Geopolymeric Setting
CEGeoGTech	-	Center of Excellence Geopolymer and Green Technology
SPCI	-	South Pacific Chemicals Industries
M	-	Molar ratio
mm	-	Millimeter

Pengeluaran Bata Geopolimer Berasaskan Abu Terbang (Fly Ash) Melalui Proses Pengeopolimeran

ABSTRAK

Penggunaan abu terbang (fly ash) sebagai bahan mentah untuk membuat bata geopolimer telah menjadi satu penyelesaian yang baik iaitu dapat memulihara sumber asli, mengurangkan pencemaran dan mengekalkan persekitaran. Geopolimer berasaskan abu terbang (fly ash) telah dikaji oleh beberapa penyelidik di seluruh dunia bagi beberapa dekad dahulu disebabkan oleh sifat-sifat mekanikalnya yang bagus. Geopolimer adalah sejenis bahan amorfus silikat alumina yang boleh disintesiskan daripada tindakbalas polikondensasi antara bahan geopolymerik dan larutan alkali. Kajian ini telah dijalankan untuk menghasilkan bata geopolimer berasaskan abu terbang (fly ash) dengan cara pembentukan melalui tekanan tanpa prosedur membakar dan juga penggunaan tenaga yang rendah. Eksperimen ini telah dijalankan ke atas bata geopolimer berasaskan abu terbang (fly ash) dengan mengubah nisbah abu terbang kepada pasir (1:2 - 1:5, oleh jisim nisbah), masa pematangan (1 - 24 jam) dan suhu pematangan (suhu bilik – 80 °C). Kekuatan mampatan, penyerapan air, ujian dimensi dan analisis ketumpatan telah ditetapkan sebagai sifat-sifat mekanikal yang perlu diuji ke atas bata geopolimer berasaskan abu terbang (fly ash). Ujian mampatan dan ujian penyerapan air telah diukur pada 1, 3, 7, 28 dan 60 hari. Hasil siasatan menunjukkan bahawa kekuatan mampatan semakin berkurang apabila nisbah abu terbang kepada pasir meningkat. Walau bagaimanapun, kekuatan mampatan meningkat dengan peningkatan dalam masa pematangan dan suhu pematangan. Kekuatan mampatan sehingga 24.3 MPa telah diperolehi pada suhu pematangan 70 °C bagi tempoh 24 jam masa pematangan pada hari ke-60. Ketumpatan bata geopolimer berkisar antara 1800 Kg/m^3 sehingga 1950 Kg/m^3. Sifat mikrostruktur bata geopolimer berasaskan abu terbang (fly ash) telah disiasat dengan menggunakan analisis XRD dan SEM.

Production of Fly Ash-Based Geopolymer Bricks Through Geopolymerization Process

ABSTRACT

Utilization of fly ash as a raw material for geopolymer brick production seems to be a logical solution that allows for the conservation of natural resources, abates further pollution and preserves the environment. Fly ash-based geopolymer have been studied by several researchers worldwide for several decades due to their excellent mechanical properties. Geopolymer is a type of amorphous alumino-silicate material which can be synthesized by polycondensation reaction of geopolymeric materials, and alkali solutions. This study has been conducted to produce fly ash-based geopolymer bricks by means of pressure forming without firing procedure and low energy consumptions. The experiments were conducted on fly ash-based geopolymer bricks by varying the ratio of fly ash-to-sand (1:2 - 1:5, by mass of ratio), curing time (1 - 24 hours) and curing temperature (room temperature - 80°C). Compressive strength, water absorption, dimensional test and density analysis was set as the mechanical properties to be tested on the fly ash-based geopolymer bricks. The compression test and water absorption test were measured at 1, 3, 7, 28 and 60 days. Results of the investigation indicated that there was decrease in compressive strength when the ratio of fly ash-to-sand increase. However, the strength was increased with increase in curing time and curing temperature. Compressive strength up to 20.3 MPa was obtained with curing at 70 °C for a period of 24 hours at 60 days of ageing. The density of geopolymer bricks ranged between 1800 Kg/m^3 to 1950 Kg/m3. The microstructural properties of fly ash-based geopolymer bricks were investigated by using XRD and SEM analysis.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Bricks are considered to be one of the oldest and the most environmentally friendly building materials. Bricks are usually used in the construction of buildings as building wall, paving and flooring. Bricks are made from variety of materials like calcium silicate and concrete and bricks made from clay are the most common. However, production of clay bricks requires high temperature (900-1000°C) kiln firing and also releases substantial quantity of greenhouse gases (Ahmari & Zhang, 2012). Due to this problem, some researchers start to use other source materials to produce construction and building bricks. One of the most popular new bricks is 'fly ash brick' and also known as 'greenest brick'. Uses of fly ash in making bricks have many advantages over conventional clay bricks as they are does not emit any pollutant and greenhouse gas during and after manufacturing, requires much less energy consumption, and it costs about 20% less than manufacturing clay bricks (Kayali, 2005).

Fly ash is a fine particulate material separated from the flue gas of coal-fired power stations which rich in alumina and silica. As the production of fly ash rising continuously and creating serious environmental pollution problems, these should not be disposed simply to prevent environmental pollution, but should be treated as a valuable resources or reuse as raw material in new technology with good properties.

American Society for Testing and Materials (ASTM) international standards classifies two class of fly ash which is class F (Low calcium) and class C (High calcium) (ASTM C 618, 2008). Class F fly ash has considerable as pozzolanic materials or pozzolans and can be activated by high alkaline solutions to act as a binder through chemical polymerization reactions (Swanepoel & Strydom, 2002). This reaction will transformed aluminosilicate materials (fly ash) into aluminosilicate polymers which are also known as geopolymers.

Geopolymer is one of new material and have been investigated, studied, and utilized for some decades by several researchers throughout the world. Geopolymer was first developed by Prof. Joseph Davidovits in St. Quentin, France, in the 1970s (Davidovits, 1989). The main properties of geopolymers are high compressive strength, low shrinkage, fast or slow setting, acid resistance, fire resistance and low thermal conductivity depending on the raw material used and processing conditions (Duxson, et. al., 2007). The geopolymer-based material involves chemical reaction known as geopolymerization process yields polymeric Si – O – Al bonds. The geopolymerization process involves a substantially fast chemical reaction under alkaline solutions on silica-alumina materials that results in a three-dimensional polymeric chain and ring structure. Much research has been studied in utilization of fly ash as source material in making of geopolymer materials. However, there is limited information that can be found in the literature regarding using the geopolymer technology to make fly ash-based geopolymer brick.

Modern application of fly ash-based geopolymer material is focused on high performance which better and more reliable quality, improved durability and high strength construction material. The development fly ash-based geopolymer brick for construction application is still at early stage. Therefore, a lot of further research on this type of brick technology needs to be carried out to enhance the quality in constructing building and other infrastructures. Compare to conventional brick used in Malaysia, fly ash-based geopolymer brick are low cost and uses of fly ash as source material in brick production can reduce the effect of environmental problems.

This research presents a design and performance evaluation of fly ash-based geopolymer brick. It proposes new technology of brick production in Malaysia and widening the possibilities to recycle waste (fly ash) to useful products especially building materials which can contribute to the environmental and economical benefits. The ultimate goal of this research is to measure, evaluate as well as to compare the performance of fly ash-based geopolymer bricks with common bricks in Malaysia based on the result obtain through this research. The performance of geopolymer brick is measured based on engineering properties present from the brick which are compressive strength, water absorption, and density. The use of fly ash-based geopolymer brick in construction application is possible but requires more research and development in the future.

1.2 Problem Statement

The main objective of this study is to create new materials to produce bricks in a way that benefits the community, the environment and industry. To achieve this, the preservation of natural resources or waste materials could be an alternative solution for progressively elimination waste and produces environmental friendly construction materials, while reducing the rate of ashes been disposed in landfill.

Every year, millions of tons of fly ash are generated from thermal power stations as well as the petrochemical industry all over the world. The abundance availability of fly ash has creating problems in disposal operations and tremendous environmental concerns. For this reason, utilization of this waste material will be beneficial when treated as valuable resource in production of good quality building materials. Brick technologists are gradually finding applications in using of fly ash as a raw material for producing greenest brick which are free from environmental pollution. Comprehensive utilization of fly ash in production of geopolymer brick which is a kind of green material contributes to social benefits and economic benefits advance together, as well as to the development of new brick with better performances.

For the above mentioned reasons, present research will be carried out to determine and understand the suitability uses of fly ash for production of geopolymer bricks and their performances as compared to common bricks used in Malaysia.

1.3 Research Aim and Objectives

The aim of the research is to develop fly ash geopolymer bricks by using geopolymerization process. This objective of this research can be summarized as follows:-

1) To produce the optimum mix proportion for processing fly ash-based geopolymer bricks
2) To identify the factors and parameters, which affect the performances of fly ash geopolymer bricks
3) To investigate the mechanical and microstructural properties of fly ash-based geopolymer bricks

1.4 Research Scope

The scope of study for this research basically to produce and study the properties of fly ash geopolymer bricks. The class F fly ash was come from the power plant Manjung, Perak, Malaysia. This study includes lab works and lab testing on fly ash geopolymer bricks. The entire tests conducted are in accordance to the standard which is American Society Testing Method and British Standard. The mechanical properties to be studied are focused on the compressive strength, density analysis, water absorption test, and dimension test. X-ray diffraction (XRD) and scanning electron microscopy (SEM) analysis was performed to investigate the microstructure properties of fly ash geopolymer bricks.

1.5 Thesis Outline

The thesis is divided into five chapters. Chapter 1 introduces the research background, aims and objectives of research, research scope, problem statement, research overview and the outline of the thesis.

Chapter 2 discusses about the literature review based on the geopolymer technology and potential use of fly ash in production of environmental friendly brick. The literature review is focused on geopolymer performance, types of experiment carried out by several researcher and application of geopolymer materials.

Chapter 3 explains the details of the materials and the methodologist implemented in the research to develop the mixture proportions, the mixing process and the curing process of geopolymer bricks. This chapter also describes the mechanical and microstructural tests of geopolymer bricks according to the ASTM and BS standard.

Chapter 4 presents the test results and discusses the findings of experimental program. The properties and effect of several factors affecting the performance of geopolymer bricks were also discussed in this chapter.

Chapter 5 states the conclusions of this study and some recommendations for the future work. The thesis ends with a Reference List and several Appendices.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The history of civilization is synonymous to the history of masonry. Man's first civilization, which started about 6000 years ago, was evident from the remains of the Mesopotamians masonry heritage. During those days masonry buildings were constructed from any available material at hand. For example, the Mesopotamians used bricks, made from alluvial deposits of the nearby River Euphrates and Tigris to build their cities beside two rivers. The Egyptian Pyramids that existed along the rocky borders of the Nile valley were examples of such stone masonry. The early forms of masonry application in Malaysia dated back about 350 years ago with the construction of the Stadthuys in Malacca, built by the Dutch in 1650. At that time, brickwork buildings were built especially for government offices, quarters and residential homes. The administrative block, Sultan Abdul Samad building built in 1894 and given a face-lift during the Fourth Malaysia Plan (1981 - 1985) is an example of a masonry heritage, which stands as a remarkable landmark of Kuala Lumpur (Zainab, 2005).

A brick is a block of ceramic material used in masonry construction, usually laid using mortar. Bricks may be made from clay, shale, soft slate, calcium silicate, concrete, or shaped from quarried stone. Brick is still used until today because of its own characteristics and due to its values and advantages. Uses of brick in the field of