STRENGTH PROPERTIES OF FLY ASH BASED GEOPOLYMER CONCRETE CONTAINING BOTTOM ASH

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To my beloved wife, Arshin

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ABSTRACT

The most important purpose of this research is concerning about the environment. Each year, vast amounts of natural resources are consumed to manufacture ordinary Portland cement which itself causes considerable environmental problems. Geopolymer can be considered as the key factor which does not utilize Portland cement, nor releases greenhouse gases. Sufficient data is available about researches on fly ash based geopolymer concrete, but using both fly ash and bottom ash has a new era. Bottom ash is another waste from the process of combustion of coal and was used as partial replacement of sand in fly ash based geopolymer concrete and the ideal percentage of this replacement was one of the aims of this project. To find 7, 14 and 28 days compressive strength, three 100×100×100mm specimens with 0, 20, 40 and 60 percent replacement of bottom ash were prepared and cured at ambient condition (28^{o}C). Same condition of curing was provided for 200×100mm cylinder specimens to determine 7-day and 28-day tensile strength and 100×100×500mm prisms were tested to find flexural strength at 7-day and 28-day of the four mixtures. Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solution 14M with ratio of 2.5 were used as alkaline activator and all other parameters were kept constant to ignore other unknown influences. The optimum rate of replacement was 20% which produced geopolymer concrete with 28-day compressive strength of 26.5MPa, tensile strength of 2.81MPa and flexural strength of 4.30MPa.

ABSTRAK

Tujuan paling penting dalam penyelidikan ini adalah mangenai penjagaan alam sekitar. Setiap tahun, sejumlah besar sumber asli digunakan untuk mengeluarkan simen Portland biasa diamana innya juga menyebabkan masalah besar pencemaran alam sekitar. Geopolymer boleh dianggap sebagai faktor utama bahan yang tidak menggunakan Portland biasa, dan tidak embebaskan gas rumah hijau. Data yang mencukupi boleh didapati tentang kajian konkrit geopolymer menjgankon terbang, tetapi menggunakan kedua-dua abu terbang dan abu dasar adalah. Abu dasar adalah sisa dari proses pembakaran arang batu diganaka sebagai bahan pengganti separa pasir dalam konkrit geopolymer peratusan yang ideal penggantian adalah matlamat projek ini. Untuk mendaptka kelwoton manpeten pada 7, 14 dan 28 hari, tiga spesimen100×100×100mm dengan peratae abu desar sebangok 0, 20, 40 dan 60 pengaweton telah disediakan dan diawet pada keadaan ambien (28^{o}C). Keadaan bagi yang sama kekuton tegege pada umur disediakan untuk spesimen silinder 200×100mm menentukan mandoptic 7-hari dan 28hari, prisma 100×100×500mm telah diuji untuk kekuatan lenturan pada 7 hari dan 28 hari. Sodium silikat (Na_2SiO_3) dan natrium hidroksida (NaOH) degen 14M yang bernisbah 2.5 digunakan sebagai alkali penggerak dan semua parameter yang lain adalah sama untuk mengabaikan pengaruh-pengaruh lain yang tidak diketahui. Kadar optimum penggantian sebangok 20% telah menghasilkan konkrit geopolymer dengan kekuatan mampatan 26.5MPa, kekuatan tegangan 2.81MPa dan lenturan 4.30MPa pada umur 28hari.

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LIST OF SYMBOLS

Al_2O_3	Alumina (Aluminum oxide)
CaO	Calcium oxide
CO_2	Carbon Dioxide
D, d	cross-sectional dimension
F	Maximum load
f_c	Concrete compressive strength
Fe_2O_3	Iron oxide
f_t	Concrete flexural strength
K_2O	Potassium oxide
KOH	potassium hydroxide
L	Length
LOI	Loss on Ignition
M	Molar
MgO	Magnesium oxide
Na_2O	Sodium oxide
Na_2SiO_3	Sodium silicate
P_2O_5	Phosphorus oxide
SiO_2	Silica (silicon oxide)

T	Time of traverse
V	Velocity of ultrasonic pulses

CHAPTER 1

INTRODUCTION

1.1 Introduction

Due to growing of population and construction, subsequently, it is obvious that the demand for space, natural resources, water, and energy will grow. The glory years for Portland cement were during 20^{th} century as a choice material for modern construction. The production of ordinary Portland cement (OPC) is rising with a rate of approximately 3% per year (McCaffrey, 2002). This huge production has two main reasons, first of all, due to the availability of the materials for its production all around the world and partly due to its versatile behavior which gave architectural freedom. Nowadays, concrete industry is known to be the major consumer of natural resources, such as water, sand and aggregates, and manufacturing Portland cement also requires large amounts of each of them. Due to its high energy consumption and environmental pollution rates, the Portland cement industry was the subject for many investigations by regulatory agencies and the public. They have believed in adjustment of the concrete industry into sustainable technology because of its role in the infrastructure development and being the main consumer of energy and natural resources. With this increasing request for infrastructural needs, it is a must for us to make a balance between the human need for preserving the environment which is endangered by the limitless use of natural resources and utilization of these natural resources. The concern about environmental issues is becoming more important and ignoring is not the solution any more.

For manufacturing each tone of the Portland cement as the primary component of concrete about 1.5 tons of raw materials is needed. Furthermore; in this process about one tone of Carbon Dioxide will be released into the atmosphere (Roy, 1999). It is produced and used in large quantities, about 175 million tons in the Europe and 1.75 billion tones worldwide. The involvement of ordinary Portland cement production to greenhouse gas production in the world is estimated to be approximately 1.35 billion tons per year or about 7% of the total greenhouse gas emissions into environment (Malhotra, 2002). It was estimated that production of OPC will increase the CO_2 emissions by about 50% from the current levels by the year 2020 (Naik, 2005). It is the main reason that many researchers believe that the manufacture of Portland cement has a remarkable influence on the greenhouse gases emission and consequently environmental impacts.

It would be a great success in case of manufacturing a concrete without any ordinary Portland cement, this can be achieved by geopolymer concrete which does not utilize any OPC in its process of production. In fact, geopolymer concrete results from the reaction of a source material with large amounts of silica and alumina with an alkaline liquid. Gourley (2003) estimated that production of a tone of geopolymer would release 164 kg of Carbon Dioxide, which is approximately one-sixth of conventional concrete emission (Alcorn, 2003).

To list the important factors in selection of the source materials to make geopolymers we can mention to cost, availability, and type of application. A wide range of mineral deposits and industrial by-products materials were became under investigation to determine the materials that are suitable for the manufacture of geopolymers. The source materials found to be suitable include natural minerals such as metakaolin, clays, etc, which contains Si, Al and oxygen in their chemical composition. Wallah and Rangan (2006) announced that by-product from other industries, for instance, fly ash, silica fume, slag, rice-husk ash, and red mud could also be applied in geopolymers as the source material.

1.2 Background of Study

The interest in the use of fly ash-based geopolymer concretes has increased since 2000 due to the environmentally sustainable option of using an industrial waste to form a useful material. In the 1970s, Joseph Davidovits a French material scientist applied the term Geopolymer for the first time, although similar materials had been developed in the former Soviet Union since the 1950s with a different name as "soil cements". The development of geopolymer concrete mix design has been carried out previously at Curtin University, Western Australia. Hardjito and Rangan (2005) investigated the effects of aspects such as alkaline parameters, water content and curing conditions in “Development and Properties of Low-Calcium Fly Ash-Based Geopolymer Concrete”. According to their studies, geopolymers are practically shapeless to semi-crystalline three-dimensional alumino-silicate polymers similar to zeolites. Geopolymers are composed of polymeric silicon-oxygen-aluminium framework with silicon and aluminium tetrahedral alternately linked together in three direction by sharing all the oxygen atoms. The negative charge created by aluminium is balanced by the presence of positive ions such as Na+, K+, and Ca+. The empirical formula of these mineral polymers is Mn [-(SiO_2) z-AlO_2] n·wH_2O, where M is an alkali cation such as potassium or sodium, the symbol - indicates the presence of a bond, z is 1, 2 or 3, and n is the degree of polymerization. Geopolymerisation is an exothermic process which consists of dissolution, transportation or orientation and polycondensation. In Malaysia, few researches were conducted on geopolymer concrete. Universiti Teknologi Malaysia (UTM) as a pioneer in advanced civil engineering materials is researching on the geopolymer concrete due to its environmentally friendly aspects and its high performances.

1.3 Problem Statement

More and more amounts of cement are manufacturing all around the world which imposes a negative impact on our living environment. Due to absence of cement in geopolymers mixture, many researchers believe that the geopolymer concrete will be the future concrete. Several by-products have been tested to produce geopolymer binders with high performances and finally, fly ash was introduced as the choice material for this purpose due to its high availability and its low cost. Although, fly ash will considerably solve problems associated with cement production, still the enormous consumption of natural resources for construction has not been solved.

Nowadays, people are aware of the consequences of the limitless utilization of natural resources. But yet, no information is available on utilization of bottom ash in geopolymer concrete. Its good properties as a fine aggregates replacement in geopolymer concrete make it a great option for sand substitution.

1.4 Objectives

The objective of this project is to investigate the manufacturing process a geopolymer concrete with different amounts of bottom ash as a replacement of fine aggregates (sand) by various mix designs to develop a concrete mixture with higher strength properties. The aim primarily is on achieving a proper mix design and a mixing method that will provide a 28-day compressive strength of at least 25 MPa.

The aims of this study can be categorized as:

(i) Studying the short term properties of fly ash based geopolymer concrete such as workability, density and water absorption
(ii) Probing the relation between velocity of ultrasonic in geopolymer concrete its compressive strength
(iii) Finding the suitable percentage of fine aggregates that can be replaced with bottom ash without significant drop in compressive strength
(iv) Investigating compressive strength development of geopolymer concrete containing bottom ash in ambient curing condition
(v) Exploring the effect of adding bottom ash on the tensile splitting strength
(vi) Finding the effect of adding bottom ash on the flexural strength of geopolymer concrete containing bottom ash

1.5 Scope of Study

This project report is investigating the short term properties of low calcium fly ash based geopolymer concrete containing bottom ash and tests mixtures with various percentages of bottom ash as fine aggregates replacement in order to find their strength properties and will not be involved with the durability aspects of geopolymer concrete. This research is only about geopolymer concrete and geopolymer mortar will not be covered by this project. This study focused on applicability of proposed methods to product concrete with adequate compressive strength that can be used as structural components. Ambient curing was selected as the method of curing which can find suitability of geopolymer concrete containing bottom ash in real structural works.

Lack of adequate standards for fly ash and bottom ash and existence of different materials with different compositions may lead to different results and conclusions. In fact, source material with different chemical composition may cause different properties in geopolymer which is a problem in comparing the results from the researches from all around the world. Event small dosage of difference in fly ash and bottom ash composition may produce large differences in results of one study to another one.