PERFORMANCE OF CONCRETE CONTAINING BLENDED CEMENT AND ARTIFICIAL LIGHTWEIGHT AGGREGATE

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DEDICATION

This master's project report is dedicated to my beloved wife Joyce who always give her care, pray and support in every single day. And also to my lovely father and lovely mother Prof. Dr. Lintje Anna who always pray for me and inspired me to pursue and complete this master project.

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ABSTRACT

The limitation of natural resources and the increasing of industrial waste materials have been a main concern in many develop countries. Therefore, many studies have been developed to investigate the feasibility of industrial by-product to be used as lightweight aggregate in concrete manufacturing. This study examined the influences of using different lightweight aggregate materials as replacement of natural aggregate and pozzolan blended cement as binder in concrete. Numbers of test were performed to investigate fresh and hardened concrete properties in terms of workability (slump), compressive strength, flexural strength, expansion and shrinkage, density, ultrasonic pulse velocity and mode of failure. The specimens consist of cube and prism were prepared and tested after 3, 7 and 28 days of water curing and air curing. Results recorded lower workability due to the high water absorption of aggregates, lower density of lightweight concrete, lower drying shrinkage due to the reduced free water content and lower pulse velocity due to air voids in concrete. However, the compressive and flexural strengths were improved by achieving 45.7 MPa and 6.7 MPa, exceeded the target strength of 30 MPa at 28 days. Therefore, the results obtained from this study might be used to produce lightweight concrete in construction industries especially for structural members.

ABSTRAK

Batasan sumber semula jadi dan peningkatan bahan sisa industri menjadi kebimbangan utama di banyak negara berkembang. Oleh itu, banyak kajian telah dibangunkan untuk mengkaji kelayakan produk sampingan industri untuk digunakan sebagai agregat ringan dalam pembuatan konkrit. Kajian ini mengkaji pengaruh menggunakan bahan agregat ringan yang berbeza sebagai pengganti agregat semulajadi dan simen campuran pozzolan sebagai pengikat dalam konkrit. Bilangan ujian dijalankan untuk menyiasat sifat konkrit yang segar dan keras dari segi kebolehmampuan (kemerosotan), kekuatan mampatan, kekuatan lenturan, pengembangan dan penyusutan, ketumpatan, kelajuan nadi ultrasonik dan mod kegagalan. Spesimen terdiri daripada kubus dan prisma yang disediakan dan diuji selepas 3, 7 dan 28 hari rendaman dan udara terbuka. Keputusan mencatatkan kebolehkerjaan yang lebih rendah disebabkan oleh penyerapan air yang tinggi, kepadatan rendah konkrit ringan, pengecutan pengeringan yang lebih rendah disebabkan oleh kandungan air bebas yang dikurangkan dan halaju nadi yang lebih rendah disebabkan oleh lompang udara dalam konkrit. Walau bagaimanapun, kekuatan mampatan dan lentur diperbaiki dengan mencapai 45.7 MPa dan 6.7 MPa, melebihi kekuatan sasaran 30 MPa pada 28 hari. Oleh kerana itu, keputusan yang diperoleh daripada kajian ini boleh digunakan untuk menghasilkan konkrit ringan dalam industri pembinaan terutamanya untuk anggota struktur.

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CHAPTER 1

INTRODUCTION

Malaysia is one of the developing countries which is still depending on the usage of concrete materials for constructions, due to the cost of concrete materials is more economical and affordable compared to the other materials. By considering the construction cost, concrete characteristic and its availability in Malaysia, it shows that researcher is trying to seek alternative materials which is more economical and affordable but durable. Nowadays, the lightweight aggregate concrete has become a popular new alternative material in construction industries. The development of Lightweight Aggregate Concrete made it possible to introduce higher strength of Lightweight Aggregate Concrete in the future, suitable for structural works designed for lower weight. Lightweight aggregate concrete has an advantage as it has lower density as much as 35% lower than the normal weight concrete. With its low density the Lightweight Aggregate Concrete has greater design flexibility, reducing dead load, less steel reinforcement, smaller size of structural, and cost savings. Recently, Malaysia has encouraged the use of “green and recycled by products” (Abubakar, 2012).

Lightweight aggregate can be produced from waste materials such as steel slag, marine clay, bottom ash (Geetha, 2010), and also can be produced from fly ash (Niyazi, 2010 and Turan, 2011). Fly ash is one of the manufacturing product that commonly used as material replacement in concrete mix.

Cement and fine aggregates are contributing an important role in terms of costs in the production of concrete, thus it becomes a major economic gain if succeed to replaced them with waste material from industrial by-product. Nowadays, the disposal problem of industrial by-products is being highly concern in many countries due to its effect on environment and also the deficit of stockpile area. Overall, this study will examine the advantage of using waste materials available in Malaysia such i.e. coal fly ash, bottom ash and ceramic waste as mineral admixtures and as substitutes materials in producing Lightweight Aggregate Concrete.

1.1 Background

Nowadays, the global warming issues has become one of the world's highest concerns. Hence, the increasing demand in the construction industry will lead to the depletion of materials used in construction sites. The concept of green technology has been declared by developing countries, but to find a good replacement materials require a great effort and commitment. With the increasing amount of concrete used, it causes natural environment and resources, such as limestone and granite, are excessively exploited. Since waste materials are available in large amount in the world, and in Malaysia as well, many researchers have conducted many studies in order to discover the appropriate replacement materials in concrete mix. However, the material used in research were high-price and difficult to obtained.

Lightweight Aggregate Concrete is still one of the advanced finding in green technology. Lightweight Aggregate Concrete produced from industrial by-product, such as ceramics, coal fly ash and bottom ash, are a new source of structural replacement materials. The main specialties of lightweight concrete are its low density and thermal conductivity compared to the normal weight concrete. Its advantages such as lower dead load, faster building rates in construction, lesser manpower required, smaller space of stockpile, lower haulage and handling costs. Weight of lightweight concrete is approximately 25% to 35% lighter but its strengths might be equal or higher than the normal weight concrete.

In this study, the concrete specimens which consist of mineral admixtures materials (pozzolanic) will be tested in order to determine the compressive strength, bending failure, and density. The materials used as mineral admixture in concrete were blended cement (Active Pozzolana Binder) to replace Portland cement (OPC), fly ash artificial lightweight aggregate to replace coarse aggregate and ceramic waste to replace fine aggregate, since these waste materials are available in large amount in Malaysia. Moreover, these product is becoming an important ingredient for improving the concrete products performance. It has been reported that more than billion tonnes of fly ash and bottom ash were produced annually worldwide in coal-fired steam power plants, but only less amount is being used, the rest were landfilled and surface-impounded without any further effort to reuse.

Cement played an important role as binder in concrete mix, considered as an expensive constituent of construction materials. Many efforts have been performed to achieve the cost effectiveness such as by using pozzolanic materials in order to reduce the amount of cement required in concrete mixing. Most pozzolanic materials are industrial by-product and their usages will lead to reduce the heat in the atmosphere (carbon footprint) due to the CO_2 emissions and energy efficiency related to cement production. Blended cement containing one of the industrial by-products materials such as fly ash, slag, silica fume is becoming a widely subject of study due to its capability to improve concrete properties. When fly ash is incorporated in concrete mix, it may improve workability, develop higher strength and resistant to freeze-thaw, however perform lower strength at eartly age (Toutanji, 2004). Most of fly ash and bottom ash are contain higher silicon dioxide (SiO_2) and calcium oxide (CaO). The use of supplementary cementitious matrials has become a worldwide trend due to some factors such as economical, ecological and higher product quality (Noor *et al.*, 2006).

Furthermore, aggregate is most widely used in reinforced concrete construction, contributing about 70-80% in concrete mix. Natural aggregates that are taken by breaking and grading natural rocks into desired size has become serious issues due to the over uses. However natural aggregates have higher density as compared with light weight aggregates. Therefore, artificial lightweight aggregate with lower density can be produced from industrial by-product thus to solve problems in environment. In this study, artificial fly ash lightweight aggregates were used in concrete mix to replace natural coarse aggregate and its effect on concrete performances were studied. Besides, the natural sand was replaced by ceramic fine aggregates ranging from zero to hundred percent by weight. The size of ceramic fine aggregates used is modified in accordance with BS 882:1992. Overall, the use of ceramic waste might reduce the environment issues with relate to natural resources availability and shortage of landfills. Ceramic raw material contains clay minerals such as kaolinite and alumina, however modern ceramic materials contains silicon carbide and tungsten carbide. Ceramic waste has been studied as having beneficial as replacement aggregate (Senthamarai, 2005 and Suzuki, 2009). Moreover, some researchers adviced that ceramic wastes are one of the good materials to be used in concrete mix. (Senthamarai, 2011 and Garcıa-Gonzalez, 2014). In this study, the use of ceramic fine aggregates as industrial by-product to replace natural fine aggregate in concrete mix were studied.

1.2 Problem Statement

The increase in the number of construction in the last few decade has resulted in over exploitation of natural resources. The natural resources used in concrete are limited, and so the sustainability of construction needs to be taken into consideration by Malaysian government. Therefore, the best way to solve this issue is by applying lightweight waste materials into concrete mix. Significantly, the lightweight concrete technology is an important development as alternative solutions in order to minimize these problems. The use of lightweight concrete allows greater design, lower cost, energy saving, and lesser steel reinforcement. The higher density of normal weight concrete leads to bigger sizes of structural members. This conditions might have few problems in construction method such as transportation, heavy equipment required, manpower and need large area for stock-pile. Many studies focused on the application of fly ash and bottom ash as partial replacement of cement and aggregate in concrete mix. However, those studies were only focus to find the optimum percentage of fly ash and bottom ash used in concrete mix. Moreover, there are less number of researcher look into the influence of combination of pozzolana blended cement, fly ash artificial lightweight aggregate and ceramic fine aggregate in producing lightweight aggregate concrete in term of its strength, pulse velocity, mode of failure and density of concrete, so there still less analysis data available. Therefore, this study will look into the development of concrete incorporated with industrial by-product of pozzolanic blended cement, fly ash artificial lightweight aggregate and ceramic waste by varying the mix proportion of concrete, in order to measure its performances.

1.3 Objectives

This study mainly focuses on the development of concrete by using proportional replacement of cement, fine aggregate and coarse aggregate. The objective for this study are:

a. To produce concrete incorporated with industrial by-product of pozzolanic blended cement, fly ash artificial lightweight coarse aggregate and ceramic fine aggregate.
b. To study the performance of concrete in terms of workability, compressive strength, flexural strength, pulse velocity, changes of length through drying shrinkage and density.
c. To determine the effects of artificial aggregates on concrete mode of failure.

1.4 Scope of study

There are many types of tests performed to evaluate the performance of concrete under different conditions. The hardened concrete is densified by pozzolanic effects from fly ash and bottom ash, which influencing its strength and permeability. Although some chemical and physical properties of pozzolanic admixtures can have a certain effect on concrete related to its performance, like where problems can arise when high carbon fly ash is used in air-entrained concrete with certain air-entraining admixes. However, this study will not concern with the pozzolanic admixtures properties. Therefore, this study will focus only on the performance of concrete containing pozzolana blended cement, fly ash artificial lightweight aggregate and ceramic fine aggregate as the fully replacement material of ordinary portland cement, coarse aggregate and fine aggregate that were assessed by the concrete compressive strength, flexural strength, expansion and drying shrinkage, and the density of lightweight concrete. The target strength for this study was 30 MPa. Meanwhile, due to time constraint, the concrete strength was tested at the ages of 3, 7, and 28 days. For the performance comparison study, one batch of normal mix concrete was prepared as a control concrete.

1.5 Significant of study

Blended cement is one of binder that was manufactured by mixing of ordinary Portland cement (OPC) and blending materials such as silica fumes, fly ash, limestone and slag in order to improve its properties. The availability of this products are high in Malaysia. Therefore, utilisations of these industrial by-product can solve the environmental problem such as the greenhouse gas emissions into atmosphere and also less of stockyard. Concrete has been used in the construction industry for few decades. The use of pozzolans such as fly ash and bottom ash have been studied and has become an innovative solution and seems successfully in improving concrete properties.

In this condition, study is required in order to investigate the performance of concrete by using blended cement, artificial lightweight aggregate and ceramic waste, and also to determine whether they are worthy to be used as cement, coarse aggregate and fine aggregate replacement materials. Moreover, this study will look at one of the ways in which engineering can contribute to this matter through promoting the recycling of industrial by products on a larger scale in the concrete industry, by utilizing the pozzolanic blended cement, artificial lightweight aggregate and ceramic waste.

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