MECHANICAL PROPERTIES OF CONCRETE INCORPORATING SPENT ABRASIVE WASTE

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DEDICATION

I dedicate this work to my family especially my mother and father.

I would like to thank Allah S.W.T for blessing me with excellent health and ability during the process of completing my thesis.

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ABSTRACT

This research presents some results and discusses the possibility of using spent abrasive waste in concrete. The key objective of this research was to determine the characteristic of spent abrasive waste including the spent garnet and spent copper slag, to investigate the appropriate amount of spent abrasive waste as substitution substances for fine aggregates and cement in concrete and in addition to investigate the mechanical properties of concrete incorporating spent abrasive waste. Various tests were carried out to determine the characteristic of materials including strength activity index, density, bulk density, sieve analysis, water absorption, ultrasonic pulse velocity and wet sieve. For mechanical properties, compressive strength, flexural strength and splitting tensile strength were tested. X-ray fluorescence was used to study the chemical composition of the materials. Spent garnet replacement level of 100% revealed the best performance regarding both water absorption of concrete and mechanical properties. In addition, the use of 20% of spent copper slag as cement replacement can produce higher compressive strength at the age of 28 days by 14% compared with control specimens. The results revealed that spent garnet and spent copper slag can be used as cement and fine aggregates replacement in concrete production as the physical and chemical properties were satisfied by the standards.

ABSTRAK

Kajian ini membentangkan beberapa hasil dan membincangkan kemungkinan penggunaan sisa buangan kasar dalam konkrit. Objektif utama penyelidikan ini adalah untuk menentukan sifat sisa buangan kasar termasuk sisa garnet dan sisa tembaga sanga, untuk mengkaji jumlah sisa buangan kasar yang sesuai sebagai bahan penganti untuk agregat halus dan simen dalam konkrit dan tambahan pula, untuk menyiasat kekuatan mekanik konkrit yang menggabungkan sisa buangan kasar. Pelbagai ujian telah dijalankan untuk menentukan ciri-ciri bahan termasuk indek aktiviti kekuatan, ketumpatan, ketumpatan pukal, analisis ayak, penyerapan air, halaju denyutan ultrasonic dan ayak basah. Bagi sifat mekanikal, kekuatan mampatan, kekuatan lenturan dan kekuatan tegangan telah diuji. '*X-fluorescence'* digunakan untuk mengkaji komposisi bahan kimia. Tahap penggantian sisa garnet sebanyak 100% menunjukkan prestasi terbaik mengenai penyerapan air konkrit dan sifat mekanikal. Di samping itu, penggunaan 20% sisa tembaga sanga sebagai pengganti simen boleh menghasilkan kekuatan mampatan yang lebih tinggi pada usia 28 hari sebanyak 14% berbanding dengan spesimen kawalan. Keputusan menunjukkan bahawa sisa garnet dan sisa tembaga sanga boleh digunakan sebagai penggantian agregat halus dan simen dalam pengeluaran konkrit kerana sifat fizikal dan kimia dipenuhi oleh piawaian.

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LIST OF ABBREVIATIONS

OPC	-	Ordinary Portland cement
CO_2	-	Carbon dioxide
SCGC	-	Self-compacting geopolymer concrete
UPV	-	Ultrasonic pulse velocity
XRF	-	X-ray Fluorescence
SG	-	Spent garnet
CS	-	Copper slag
S	-	Sand
R^2	-	Coefficient of determination
Fe_2O_3	-	Ferum Oxide
SiO_2	-	Silica Oxide
Al_2O_3	-	Aluminium Oxide
CaO	-	Calcium Oxide
MgO	-	Magnesium
MnO	-	Manganese
TiO_2	-	Titanium Dioxide
K_2O	-	Potassium Oxide
P_2O_5	-	Phosphorus Pentoxide
ZnO	-	Zinc Oxide
Cr_2O_3	-	Chromium(III) Oxide
LOI	-	Loss of Ignition
SO_3	-	Sulphur
Cl	-	Chloride
CuO	-	Copper Oxide

LIST OF SYMBOLS

P	-	Ultimate compressive load of concrete
A	-	Surface area in contact with the plates
R	-	Modulus of rupture
L	-	Span length
b	-	Average width of specimen
d	-	Average depth of specimen
T	-	Splitting tensile strength
V	-	Pulse velocity
T	-	Transit time
D	-	Density (unit weight) of concrete
Wc	-	Mass of the concrete
Vc	-	Volume of the measure
Wa	-	Percentage of water absorption
Ww	-	Weight of wet specimen
Wd	-	Weight of dry sample
M	-	Bulk density of the aggregate
G	-	mass of the aggregate plus the measure
V	-	volume of the measure
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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is a composite material which is made of filler and a binder that is widely used in construction. Concrete mix generally consists of cement, aggregates (sand and granite), and water mixed together. Materials such as sand and gravel form the most part of the aggregates. According to Omar *et al*., (2016), about 70-80% of aggregates represent in concrete components. Continuous extraction of aggregates has caused resources depletion at an increasing rate. Reported by Muttashar *et al*., (2018), the growing use of sand from the river for some purpose of construction, which led to the use of more rivers' bed and disturbed the ecosystem. Therefore, there is a need in finding new material to solve this problem.

A study by Abdel-Hay, (2015), a lot of wastes are produced every day from construction and demolition such as concrete, bricks, ceramics, rubber and glass (Verian *et al.*, 2018). Some wastes are being handled properly but some are not. These wastes would be beneficial if they are processed into something that could be used in construction. According to Muttashar *et al*., (2018), waste materials such as spent garnet can develop sustainable product and at the same time will reduce the cost which proves to be most economical.

Meanwhile, the production of one tonne of Ordinary Portland Cement (OPC) can generate one tonne of carbon dioxide (CO_2). Such high rates of emission of CO_2 significantly contribute to global warming and climate change (Ariffin and Hussin, 2015). Due to the increasing cost of material, replacement of OPC with waste material such as copper slag which can offer the opportunity to get efficient construction materials via their appropriate recycling method. Using it as cement is if permitted, it will be more convenient, economical in the construction field.

According to Zhang *et al*., (2018), the possible way to use copper slag is to use it in concrete production. Due to the increasing of large required area for disposal of this waste, there are many ways to use it such as in the construction of pavement. Al-Jabri *et al*., (2011) reported that copper slag is materials that qualify to be used in concrete production as replacement of OPC. According to Uysal *et al*., (2011), waste material can decrease the permeability of concrete. Replacement of cement is not only helps in their strength and durability. It also helps in reducing the cost of cement and also has numerous benefit (McGinnis *et al*., 2017). Therefore, exploring this abrasive waste as cement and fine aggregates replacement in concrete would create an advanced waste material. This will also help improve the performance of concrete and reduce the landfill problem of waste disposal.

1.2 Problem Statement

Over the last decade, the demand for natural resources has increased so far that it is now considered a serious threat to our economic and social balance. The process of producing cement not only depleted the natural resources such as limestone and clay but can cause serious impact on the environment. In addition, the continuous extraction of natural aggregate can causes soil erosion and destruction of the ecosystem (Kim *et al*., 2016).

The production of cement involves large quantities of raw materials, energy, and heat. Besides, the higher amount of OPC used in concrete production can be affected by the presence of pollutions in the environment such as CO_2, sulphur oxides and suspended particulate matter (Rambabu, 2017). There are a ways to limit the consumption of OPC, one of it is employing of copper slag in concrete production. Some research revealed the effects of concrete content OPC suffered the highest rise in permeability and porosity (Pavía and Condren, 2008). In order to find a more durable and dense concrete in this environment, incorporating pozzolanic material such as spent copper slag in concrete production is needed. In addition, nearly 68.7 million tonnes of copper slag is generated per year and will cause risks of pollution. This is because of no proper way to treating the copper slag waste and the way to dispose the copper slag in a sustainable way is employing in concrete production (Zhang *et al*., 2018).

Furthermore, there is an increasing demand to find another material as alternative materials to be used as aggregate in concrete. A recent assessment of the Malaysian shipyard industry revealed that the country import approximately 2000 million tonnes of spent garnets in the year 2013 alone and the quantities are widely discharged as waste (Muttashar *et al*., 2018). Spent garnet is considered as one of the serious problems of waste generation by the industries. Besides, spent garnet can be used for production of new concrete by replacing natural fine aggregates such as sand at different levels of construction.

The sustainable development for construction involves use of non-conventional and innovative materials, and reuse waste material to compensate for the lack of natural resources and to find an alternative way to preserve environment (Ambily *et al*., 2015). Additionally, using of waste material had a good influence on the performance of concrete. Use of spent garnet and spent copper slag can reduce manufacturing waste which usually ends at the landfills. On the other hand, it can save the use of natural resources.

Therefore, in order to evaluate the potential use of spent garnet and spent copper slag from shipyard industries, a comprehensive study on the fundamental characteristic of materials and mechanical properties of concrete are necessary.

1.3 Aim and Objectives

The aim for this research is to study the effect of spent garnet and spent copper slag on mechanical properties of concrete. The specific objectives are as follows:

1. To determine the characteristic of spent garnet and spent copper slag as fine aggregates and cement replacement in concrete.

2. To investigate the appropriate amount of spent garnet and spent copper slag as substitution substances for cement and fine aggregates in concrete.

3. To investigate hardened properties of concrete incorporating spent garnet and spent copper slag.

1.4 Scope of Study

The scope of the study will focus on the use of spent garnet and spent copper slag as the replacement of fine aggregates and cement in concrete production. The spent abrasive wastes are acquired from Malaysia Marine and Heavy Engineering (MMHE).

The first stage deals with characterization of materials and testing of the properties of spent garnet and spent copper slag. These comprise; strength activity index, density, bulk density, sieve analysis, water absorption, specific gravity and wet sieve. It also deals with the determination of the chemical compositions of spent copper slag by X-ray fluorescence (XRF).

The second stage deals with mix design and proportioning of the materials for concrete. The percentages of spent garnet replacement into the concrete mixer are 0% (as control), 25%, 50%, 75% and 100%. Trial test will determine the appropriate amount of spent garnet and it will be used as benchmark. The mechanical properties for trial test are to be conducted at the age of 7, 14 and 28 days. The mineral admixture used in this study is spent copper slag which replaced the amount of OPC. The percentage of spent copper slag will be used as cement replacement are 10%, 20% and 30%.

The third stage deals with the investigation of hardened state properties. For hardened state properties of concrete, the mechanical properties including compressive strength, splitting tensile strength and flexural strength are to be conducted at the age of 7, 14 and 28 days after curing process. In addition to compressive, tensile and flexural strength tests, density, ultrasonic pulse velocity and water absorption was also conducted to examine the relationship. Concrete were design according to Department of Environment (DoE) method with 50 MPa at 28 days. The procedure will be used based on ASTM Standard and BS Standard.

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