EFFECT OF PALM OIL FUEL ASH (POFA) WITH LIMESTONE AS A PARTIAL CEMENT REPLACEMENT MATERIAL TOWARDS COMPRESSIVE STRENGTH AND CORROSION RESISTANCE

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ABSTRACT

Malaysia is a country with a lot of agricultural products that can be used to increase Malaysia's economy. With the growing concern nowadays about the problem of pollution together with the increasing level of waste product from the factory, many researchers were focusing on how to maximizing the utilization of agricultural and industrial waste. One of the by-products was palm oil fuel ash (POFA). POFA is the grey stuff with seem black which an agro-waste resulting from the incineration process at temperature about 800°C - 1000°C of oil palm residue. POFA will acts as a natural pozzolana in a partial replacement of cement. This can be done together with the addition of limestone. For this research, the relationship when there is an addition of limestone as a partial cement replacement material in concrete and where there is only POFA as pozzolana was investigated. The aim of the study is to investigate the effect of POFA with limestone as a partial cement replacement material in term of concrete compressive strength and corrosion resistance. Ordinary Portland Cement (OPC) has been partially replaced with 20% of POFA only and 20% POFA with 5% and 10% of limestone respectively. For compressive strength test, cube sample of 150mm × 150mm × 150mm that were cured for 7, 28 and 90 days have been used. As for the water permeability test, cube sample of 100mm × 100mm × 100mm that were cured for 28 and 60 days have been used. Cylinder in the form of 80mm in diameter and 160mm height and were cured for 28 days has been used for impressed voltage test. For the compressive strength test, the control without any replacement of cement shows the highest strength. As for the permeability test, the control shows the highest permeability of concrete but in impressed voltage test, concrete with 20% partial replacement of cement with POFA shows the same reading as control. As a conclusion, it is found that replacement of cement with 20% of POFA can reduce the corrosion but not in compressive strength and water permeability of concrete.

ABSTRAK

Malaysia ialah negara yang mempunyai banyak produk pertanian yang menjadi tunjang kepada peningkatan ekonomi di Malaysia. Dengan kebimbangan yang semakin meningkat ke atas masalah pencemaran dan peningkatan kadar pembuangan bahan terbuang dari kilang, ramai penyelidik mengambil fokus mengenai cara memaksimumkan penggunaan sisa pertanian dan perindustrian. Salah satu produk sampingan adalah abu bahan api kelapa sawit (POFA). POFA akan bertindak sebagai pozzolana semulajadi dalam pengganti separa simen. Ini boleh dilakukan bersama-sama dengan tambahan batu kapur. Untuk kajian ini, hubungan apabila terdapat penambahan batu kapur sebagai bahan separa gantian simen di dalam konkrit dan di mana hanya ada POFA sebagai pozzolana dikaji. Tujuan kajian ini adalah untuk mengkaji kesan POFA dengan batu kapur sebagai bahan separa gantian simen dari segi kekuatan mampatan konkrit dan rintangan kakisan. Ordinary Portland Cement (OPC) separuh digantikan dengan 20% POFA dan digantikan dengan 20% POFA bersama dengan 5% dan 10% batu kapur. Untuk ujian kekuatan mampatan, sampel kiub 150mm × 150mm × 150mm yang direndam selama 7, 28 dan 90 hari telah digunakan. Bagi ujian kebolehtelapan air, sampel kiub 100mm × 100mm × 100mm yang direndam selama 28 dan 60 hari telah digunakan. Silinder dalam bentuk 80mm diameter dan 160mm tinggi yang telah direndam selama 28 hari telah digunakan untuk ujian teknik kesan voltan. Untuk ujian kekuantan mampatan, sampel tanpa sebarang penggantian simen menunjukkan kekuatan tertinggi. Bagi ujian kebolehtelapan air, sampel tanpa sebarang penggantian simen menunjukkan kebolehtelapan tertinggi konkrit tetapi dalam ujian teknik kesan voltan, konkrit dengan 20% penggantian sebahagian simen dengan POFA menujukkan bacaan yang sama seperti sampel tanpa sebarang penggantian simen. Kesimpulannya, didapati bahawa penggantian simen dengan 20% POFA sahaja akan mengurangkan hakisan tetapi tidak mempunyai kekuatan mampatan dan kebolehtelapan air oleh konkrit.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Al	Aluminium
Al_2O_3	Aluminium trioxide
As	Arsenic
As_2O_3	Arsenic trioxide
ASTM	American Society for Testing and Materials
BS	British Standard
Ca	Calcium
CaO	Calcium oxide
$Ca(OH)_2$	Calcium hydroxide
Cl	Chlorine
CO_2	Carbon dioxide
Cr	Chromium
Cr_2O_3	Chromium (III) oxide
C-S-H	Calcium silicate hydrate
Cu	Copper
CuO	Copper oxide
DOE	Department of Environmental
Fe	Iron
Fe_2O_3	Iron oxide
FYP	Final Year Project
JKR	Public Work Department of Malaysia
K	Potassium
K_2O	Potassium oxide

LOI	Loss of Ignition
Mg	Magnesium
MgO	Magnesium oxide
Mn	Manganese
MnO	Manganese (II) Oxide
Na_2O	Sodium oxide
Nb	Niobium
Nb_2O_5	Niobium pentoxide
Ni	Nickel
NiO	Nickel oxide
OPC	Ordinary Portland Cement
P	Phosphorus
P_2O_5	Phosphorus Pentoxide
POFA	Palm Oil Fuel Ash
POME	Palm oil mill effluent
Rb	Rubidium
Rb_2O	Rubidium oxide
S	Sulphur
SEM	Scanning Electron Microscopy
Si	Silicon
SiO	Silica oxide
SiO_2	Silicon dioxide
SO_3	Sulphur trioxide
Sr	Strontium
SrO_2	Strontium Oxide
Ti	Titanium

TiO_2	Titanium Dioxide
w/c	Water cement ratio
Zn	Zinc
ZnO	Zinc oxide
Zr	Zirconium
ZrO_2	Zirconium Dioxide

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Agriculture is one of the most important sectors towards the increasing of Malaysia's economy. The main crops such as oil palm, rubber and cocoa have dominated in this sector for export. Other than that, agriculture also produced the main source of solid waste and following then by industrial municipal and mining sources. Oil palm also produced a few types of wastes such as empty fruit bunch, palm oil mill effluent (POME) and palm oil fuel ash (POFA). POFA is the grey stuff with seem black which an agro-waste resulting from the incineration process at temperature about 800°C - 1000°C of oil palm residue (Jumaat, 2010).

Today researches from all over world are now focusing on how to maximizing the utilization of agricultural and mostly industrial wastes and use it in the construction industry. The utilization of these wastes product may not be economical but it will help to create a sustainable and a pollution free environment.

Presently various types of by-product materials such as fly ash, blast furnace slag, silica fume, rice husk ash and others have been widely used as pozzolanic material in concrete. Their utilization not only improves the concrete properties, but also preserves the environment (Lee et al., 2010). The use of POFA with limestone as a cement replacement material will help to improve the compressive strength and corrosion resistance of the concrete.

Most cement plants consume much energy and produce large amount of undesirable products, which affect the environment. In order to reduce energy consumption and carbon dioxide, CO_2 emission and increase production, cement manufacturers are blending or inter-grinding mineral additions such as slag, natural pozzolana, sand and limestone (Kenai et al., 2004).

Natural pozzolana has been widely used as a Portland cement replacement material in many applications. This is because it can reduce the cost, reduce the heat evolution, decrease permeability and increased chemical resistance. However they are often associated shortcomings such as the need to moist curing for longer time and a reduction of strength at early ages and up to 28 days (Kenai et al., 2004). The reactivity of limestone fillers shows the change in the C-S-H and the formation of transition zone between the filler and cement paste (Bonavetti et al., 2001; Kakali, 2000 and Heikal et al., 2000).

1.2 PROBLEM STATEMENT

Recently, there are a lot of polluted wastes that was being emitted by the factory or by any other resources in Malaysia. For example, there is an increase in amount of the emission of carbon dioxide gasses by the factory. There was also a lot of energy consumption. Therefore, utilization of industrial and

agricultural waste products in the industry has been the focus of research for economic, environmental and technical reasons.

Fly ash and silica fume are widely used as pozzolans in high strength concrete. There are also a few researches on using rice husk-bark ash or palm oil fuel ash was reported. To obtain more information of these materials, various by-product materials from industries are used to substitute Portland cement to make high strength concrete (Sata et al., 2007).

In order to investigate the effectiveness of these pozzolans which are POFA and limestone as partial cement replacement materials, a few mechanical testing and testing towards corrosion resistance will be done. The relationship when there is an addition of limestone as cement replacement material in concrete and when there is only POFA as pozzolan will be also known. Is limestone give a better result on concrete, will be investigate.

1.3 RESEARCH OBJECTIVES

The aim of this research is to study the effect of POFA with limestone as a partial cement replacement material. The related objectives of the present research are as follows:

i. To investigate the effect of POFA with limestone as a partial cement replacement material towards concrete compressive strength.

ii. To determine the effect of POFA with limestone as a partial cement replacement material towards corrosion resistance.

1.4 SCOPE OF STUDY

This study focused on the investigation of POFA concrete, POFA with limestone as a partial cement replacement material in concrete and a control mix of plain concrete. In this study, each sample of concrete was being designed with grade 30. The constant water cement ratio (w/c) of 0.5 was conducted. The plain concrete or the control mix consist of cement, water, aggregate and sand without replacing with any POFA or limestone (control). The second sample composes of cement, water, aggregate, sand and POFA as cement replacement comprises of 20% from the total weight of Ordinary Portland Cement (POFA20 + limestone0). Another two samples comprise of cement, water, aggregate, sand and 5% and 10% of limestone together with 20% of POFA from the total weight of Ordinary Portland cement respectively (POFA20 + limestone5) and (POFA20 + limestone10).

For the preparation of the sample, the aggregate the concrete were mix according to the specification. After being mixed, the mix was being poured into the cube mould of size (150 mm × 150 mm × 150 mm) for compressive strength test and cube mould of size (100 mm × 100 mm × 100 mm) for water permeability test. As for the impressed voltage test, the mix will be poured into the cylinder mould of 80 mm in diameter and 160 mm height. The process of taken out the concrete from the mould can be done after 24 hours to harden the concrete. The hardened concrete was cured for 9, 28, 60 or 90 days in water for all mixes according to respective tests.

The compressive strength tests were done for each of mix. They were tested at the ages of 7, 28 and 90 days by using compression testing machine and accessories after the sample has been matured.

Another three samples from each mix will be tested for water permeability test. The concrete will be tested by using concrete permeability apparatus. The initial and final level of the water will be measured to know the rate of water permeability of the concrete.

Then, the two samples from each mix will be tested for the corrosion resistivity of the concrete. The concrete mix will be poured into concrete cylinder mould. One steel reinforcement bar of size 12mm in diameter will be cast together with each of the concrete mix. The test that will be done is impressed voltage test. The chemical solution that will be used is sodium chlorine solution.

1.5 SIGNIFICANT OF STUDY

There are many problems that have been encountered by the environment or by the human being because of the production of the cement. There were a lot of carbon dioxide gasses that will be emitted by the factories producing cement. These have been a major greenhouse gas towards the environment.

Furthermore, there are a variety of waste materials that have been produced by the factories in Malaysia. All of these waste materials can be reused or recycled for many other uses. The waste materials that have discussed are about POFA and limestone. In order to reduce the production of cement that gave a bad impact to the environment, these waste materials can be used as cement replacement material.

All of the mixture that contains POFA and the limestone as cement replacement material has to be tested according to the mechanical properties and towards corrosion. These is to ensure that the replacement of this material in cement production give a good impact in the environment. Not only that, the modified concrete also can give a more quality construction material in future.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In civil engineering projects, there is a widely used of high-strength concrete throughout the world. This is because most of its mechanical and durability properties are better than those of normal-strength concrete. In addition to the advantageous properties, using high-strength concrete will be able to reduce the size of structural members that are essential in high-rise buildings especially for beams and columns. The use of lighter and slender structures can reduce the volume of concrete needed in building structures as well as to save cost for construction projects (Tangchirapat et al., 2009)

Rapid industrialization results in increased use of natural resources together with serious ecological and environmental imbalance due to the dumping of industrial wastes (Ondova et al., 2014). The pollution and health hazards especially related to concrete, cement and clay-bricks industries are coming under intense scrutiny from environmentalists and the governments. This is because of the growing environmental consciousness at all levels of society. The developed countries are farther ahead in tackling the problem by

using industrial and agricultural wastes in their industries. Million tons of these waste materials are abundantly available and discarded every year in the world. These industrial and agricultural wastes are mostly the by-products of oil and coal burning by-products, slag, rice husk ash bagasse, fly ash, cement dust, stone crusher dust, marble dust, brick dust, sewer sludge, glass, tires and many more (Khan, 2012).

2.2 POZZOLANA

Pozzolanic materials have long been in practice since the early civilization either in the way of naturally occurring or artificially made. Nowadays, the utilisation of pozzolanic materials in concrete construction has become increasingly widespread. Not only that, this trend is expected to continue in the years ahead because of technological, economic and ecological advantages of the materials (Awal et al., 2013).

Generally a pozzolanic material has little or no cementing property. However, when it has a fine particle size with the presence of moisture, it can react with calcium hydroxide, $Ca(OH)_2$ at ordinary temperatures to provide the cementing property (Tangchirapat, 2007).

2.3 PALM OIL FUEL ASH (POFA)

2.3.1 Origin of POFA

The oil palm is a tall-stemmed tree which originated from palm family Palmea. The countries in the equatorial belt that cultivate oil palm are Benin

Republic, Colombia, Ecuador, Nigeria, Zaire, Malaysia and Indonesia of which Malaysia is the largest producer of palm oil and palm oil products (Deepak, 2014).

It has been estimated that the total solid waste that has been generated by the industry in Malaysia itself has reach to about ten million tons a year (Safiuddin et al., 2011).

POFA is a by-product from palm oil industry. POFA is a waste that is obtained from burning palm oil fibres, shells and empty fruit bunches as fuel to produce steam for generating the electricity for palm oil extraction process (Sata et al., 2007). It will be burnt at temperatures of about 800-1000°C to produce steam for electricity generation in biomass thermal power plants (Tangchirapat et al., 2009). POFA is increasing years by years especially in Malaysia, Thailand and Indonesia.

POFA is a waste material of which poses enormous environmental pollution. This ash is simply disposed of without any commercial return. It has been proven that POFA has good pozzolanic properties that can be used as a cement substitute in mortar and concrete mixes (Deepak, 2014). Figure 2.1 shows the production of more than 2 million tons of solid waste of palm oil residue, such as palm fiber, shells, and empty fruit bunches annually.

Figure 2.1: An overview of palm oil residues

2.3.2 POFA as Cement Replacement Material

POFA is one of the agro waste ashes in which the chemical contains a large amount of silica and is has a high potential to be used as a cement replacement material (Tangchirapat et al., 2009). If POFA is being used as a pozzolanic material in producing high-strength concrete and to improve the durability of the concrete, it will also lead to the reductions in cement usage. The cost of high-strength concrete will also reduce as well as beneficial for the environment by reducing the volume of waste disposed of in landfills. Other than that, using POFA as a replacement for cement will also encourage researches to investigate the use of other by-products from biomass power plants, which will ultimately lead to their development as a more environmentally friendly way of generating energy (Tangchirapat et al., 2009). Figure 2.2 shows the POFA that is disposed of as waste in landfills causing environmental and other problems (Tangchirapat, 2007).