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STUDY ON DURABILITY OF HIGH STRENGTH
PALM OIL FUEL ASH POFA CONCRETE

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structure and Material)

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NOVEMBER 2008

I declare that this project report entitled “*study on durability of high strength palm oil fuel ash POFA concrete*” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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DEDICATION

Praise be to Allaah, the Lord of the Worlds

Who says (interpretation of the meaning):

“Give thanks to Me and to your parents. Unto Me is the final destination”

[Quraan, Luqmaan 31:14]

All glory and honor to Him

Then I dedicate this work to my mother, father, and to all who supported me by Doa, work and thinking as much as each of them has supported.

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ABSTRACT

The use of Palm Oil Fuel Ash (POFA) which is a pozzolanic material as a partial cement replacement for producing concrete will reduce the cost of concrete, environmental pollution problems, as well as cutting down the number of landfill areas required for disposing the ash. Although POFA has low pozzolanic property with large particles, it can be one of the effective agrowaste ashes when its fineness increases. In this investigation, POFA was ground to increase its degree of fineness as well as to improve its reactivity when added in the concrete mix. The present study designed to determine the effect of POFA fineness towards the durability of high strength POFA concrete in term of increasing its resistance towards chemical attacks namely sulfate, acid and chloride penetration. In this experimental study, 2 types of mixes were prepared using ash possessing different fineness namely 45 μm and 10 μm and a control mix with 100 % OPC. The entire POFA high strength concrete specimens prepared consist of 20 % POFA as partial cement replacement material. Conclusively, integration of POFA as partial cement replacement, especially very fine POFA increase the resistance of high strength POFA concrete towards chloride, acid and sulfate attack .

ABSTRAK

Penggunaan abu kelapa sawit (POFA) yang merupakan bahan pozzolana sebagai bahan pengganti simen dalam pembuatan konkrit akan mengurangkan kos konkrit dan masalah pencemaran alam sekitar di samping mengurangkan bilangan tapak pelupusan yang diperlukan bagi membuang abu ini. Walaupun POFA mempunyai sifat pozzolana yang rendah dan terdiri dari saiz partikel yang besar, ia boleh digunakan sebagai abu yang efektif apabila kehalusan bahan ini bertambah. Dalam penyelidikan ini, POFA telah dikisar bagi meningkatkan darjah kehalusan serta kereaktifannya apabila ditambah ke dalam bancuhan konkrit. Kajian ini direkabentuk untuk menentukan kesan kehalusan POFA terhadap ketahanan lasakan POFA konkrit berkekuatan tinggi dari segi meningkatkan ketahanan terhadap serangan kimia iaitu sulfat, asid dan penusukan klorida. Dalam kajian eksperimental ini, 2 jenis bancuhan telah disediakan menggunakan abu yang mempunyai darjah kehalusan yang berlainan iaitu 45 μm dan 10 μm serta bancuhan kawalan mengandungi 100 % OPC. Kesemua POFA konkrit berkekuatan tinggi yang dihasilkan mengandungi 20 % POFA yang berfungsi sebagai bahan separa pengganti simen. Kesimpulannya, penambahan POFA sebagai bahan separa pengganti simen terutamanya, POFA yang sangat halus meningkatkan ketahanan POFA konkrit berkekuatan tinggi terhadap serangan klorida, asid dan sulfat.

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LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ASTM	American Society of Testing of Materials
BRE	Building Research Establishment
BS	British Standards
C ₂ S	Dicalcium Silicate
C ₃ A	Tricalcium Aluminate
C ₃ S	Tricalcium Silicate
C-A-H	Calcium Aluminate Hydrate
C-S-H	Calcium Silicate Hydrate
CaO	Calcium Oxide
CH	Calcium Hydrate
LOI	Loss On Ignition
MgO	Magnesium Oxide
Na ₂ O	Sodium Oxide
OPC	Ordinary Portland Cement
PFA	Pulverised Fuel Ash
POFA	Palm Oil Fuel Ash
RHA	Rice Husk Ash
SiO ₂	Silicon dioxide
SO ₃	Sulphur Oxide
XRD	X-ray diffraction

CHAPTER 1

INTRODUCTION

1.5 General

There has been so much demand on construction materials in many countries around the world. Concurrently with the rapid expansion of construction activities, housing and other building, at the same time the rising cost of production with very serious shortage on construction material that will play a critical role in our long term future. The discovery of the alternative of conventional building materials that is cheaper and accessible became highly critical issue.

Due to the limited utilization of waste materials, the rate on which they disposed as landfill materials is expected to increase consequently leading to potential future environmental problem. Accumulation, burning and landfill of solid waste disposal could be expensive and undesirable. Reuse these materials in workable areas such as in the construction industry which is considered as very active area over the entire world is a current practice.

1.6 Background Information

1.2.1 The Problem

Strength and durability are the targets in any concrete mix design, and to achieve these targets pozzolanic material has to be involved. Cement is well known as one of the most important ingredient in the concrete mix, which means it is essential to use cementations materials in any construction activities. Recently, many countries around the world are facing the problem of cement shortage; moreover in term of energy consuming the Portland cement consider the highest.

However, the industrial or agricultural wastes can be developed to generate new cement substitutions together with the effective and efficient utilization of existing materials. The amount of supplementary cementations materials is still below the level of demanding of cement although the utilization of them increased but still limited to specific area of application. Proving and improvement of those new discovered material are not really sufficient enough to make use of those materials. Therefore, full profitable utilization can be achieved by further development and adjustment for the material that have been studied to some point.

1.2.2 Pozzolanic Ash as Cement Substitute

There is no disbelief that the inclusion of pozzolanic material, both naturally occurring or artificially made, as a partial cement replacement passes on significant enrichment of the basic characteristics of the resulting mass either in its fresh and hardened states. Nowadays, of all the silicon by-products, fly ash or pulverized fuel ash (PFA) are possibly the most widely used globally. Added to this is the fact that fly ash makes considerable changes to the strength and durability aspects of concrete that are well documented in national codes and standards.

Separately from industrial waste, ashes from agricultural source like rice husk, coconut husk, palm oil husk, peanut shell or fiber shell etc. have been used for making cement substitutes (Bentur *et al.*, 1986; Abu, 1990; Mehta, 1992; Nimityongskul and Daladar, 1993). Among them, rice husk ash (RHA) is highly rich and has been distinguished as the most active pozzolan in making high performance concrete and cement products. Previously, numerous works have been carried out to look into the various aspects of ashes with pozzolanic behaviour, and in many parts of the world these materials have already been known as supplementary cementing materials.

1.2.3 Palm Oil Fuel Ash: A New Pozzolanic Material

Malaysia is the world's leading producer and exporter of palm oil and palm oil products with a reputation for quality and consistency. To date, there are more than

two hundred palm oil mill plants operating in the country that are self sufficient industry as far as energy utilization is concerned. On average, 43 tons or more empty fruit bunches, fibres and shells are generated per 100 tons of fresh fruit bunches processed. It has been approximated that the total solid waste generated by this industry has amounted to more than 8 million tons a year (Rashid and Rozainee, 1993). The palm fibre and shell obtained as waste products by the industry are generally used as boiler fuel to produce steam for electricity generation and palm extraction process. The ash produced by burning palm fiber and shell is considered to be a waste product, the disposal of which causes lot of problems. As a normal practice this ash is dumped into wastelands behind the mill. Experimental laboratory studies, however, have shown that this ash has good pozzolanic properties that make possible the replacement of cement in mortar and concrete mixes. Although identified with various names namely palm oil fly ash (Abu, 1990; Samsuri and Subbiah, 1997) and oil-palm ash (Tay, 1990). (Salihuddin, 1993) is the pioneer researcher to mark this as palm oil fuel ash or POFA (Abdul Awal, 1998).

1.7 Objectives and Scope of Research

In view of the utilisation of POFA as a partial supplementary cementing material of ordinary Portland cement, research programmes have been started at the Faculty of Civil Engineering of the Universiti Teknologi Malaysia to examine various properties of mortar and concrete since the late eighties (Salihuddin and Abu, 1989; Salihuddin and Hussin, 1993a). Taking into consideration the availability and its natural pozzolanic property, the objectives of the present research, in brief, have been set to study the effects of palm oil fuel ash as partial replacement of ordinary

Portland cement on some properties of high performance concrete with particular emphasis on durability aspects of high strength concrete.

Detail investigations on some properties of the ash have been evaluated. for mortar bars prepared for measuring expansions due to sulphate attack and all the test specimens were made up of concrete where OPC was replaced, mass by mass, by amounts of POFA with 45 μm particle size of 20 % and by amount of POFA with less than 10 μm particle size of 20 %. The durability aspects considered in this study were: resistance to aggressive chemicals like acid, sulphate, and chloride ions. Tests on Sulphate expansion with the aim of assessing the effectiveness of fineness of POFA in preventing expansion due to the Sulphate have been conducted.

1.8 Research Hypothesis

Palm oil fuel ash (POFA) can successfully be used as a partial cement replacement material in making high strength durable concrete subjected to the fineness of the ash.