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THE EFFECTS OF POFA FROM DIFFERENT SOURCES ON DURABILITY OF HIGH STRENGTH CONCRETE IN MALAYSIA

SALEH OMAR AHMED BAMAGA

A project report submitted in partial fulfillment of the requirements for the award of the degree of Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
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APRIL 2010

I declare that this project report entitled "*the effects of POFA from different sources on durability of high strength concrete in Malaysia*" 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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Date : APRIL 2010

To my beloved parents, supportive wife and brothers
and
my lovely sons

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ABSTRACT

This paper presents the effects of using palm oil fuel ash (POFA) from different sources as pozzolanic materials on durability of high strength concrete. Different types of POFA were ground until the particle size was reduced to 45 µm. They were used to partially replace Portland cement Type I, by 20% by weight of binder. Nine types of concretes containing POFA collected from different palm oil mills in addition to ordinary Portland cement concrete (CT 1) were investigated and tested for compressive strength for ages of 7, 28 and 90 days. Also, they were tested and compared for chloride resistance using rapid chloride penetration test (ASTM C1202) and salt ponding test (ASTM C1543). For the durability of mortar exposed to sulfate attack, 25 x 25 x 285 mm mortar bars were prepared and cured according to ASTM C1012 (89)-1994 prior to immersion in 5% sodium sulfate $Na_2(SO)_4$ and magnesium sulfate $Mg(SO)_4$ solutions for up to 15 weeks. The expansion of mortars containing POFA from different sources after immersion in $Na_2(SO)_4$ was lower than that mortar made of pure portland cement. For immersion in $Mg(SO)_4$, only RAPOFA, TRPOFA and PAPOFA mortars showed higher expansion than that of pure portland cement mortar. Four cubes of 100 mm size were tested on comprerssive strength and the average was reported. The results showed that all concretes except BIPOFA, MAPOFA and KTPOFA achieved compressive strength higher than 41 MPa that required for high strength concrete as per ACI 363. Quality of all concretes containing POFA from different sources except MAPOFA was significantly improved in terms of chloride resistance.

ABSTRAK

Kesan pengguaan abu pembakaran minyak sawit (POFA) terhadap ketahanan konkrit berkuatan tinggi daripada sumber yang berbeza sebagai bahan pozzolana dipersembahkan dalam kertas ini. Pelbagai jenis POFA di kisar sehingga bersaiz 45 µm. Ia diguna untuk menggantikan simen portland jenis 1, dengan 20% berat pengikat. Sembilan jenis konkrit mengandungi POFA diambil daripada kilang minyak kelapa sawit yang berbeza dan konkrit simen portland (CT 1) dikaji dan diuji untuk kekuatan mampatan 7, 28 dan 90 hari. Ia juga duiji dan dibandingkan untuk rintangan klorida menggunakan ujian penurasan deras kolrida (ASTM C1202) dan ujian ikatan garam (ASTM C1543). Kebolehtahanan pendedahan mortar bersaiz 25 x 25 x 285 mm disediakan dan diawet mengikut ASTM C1012 (89)- 1994 sebelum direndam dalam 5 % sodium sulfat dan magnesium sulfat sebatian selama 15 minggu. Penggembagan mortar mengandungi POFA daripada sumber berbeza selepas direndam dalam Na_2SO_4 adalah rendah berbanaing dengan mortar simen portland tulin. Bagi rendaman dalam $MgSO_4$, hanya RAPOFA, TRPOFA, CAPOFA dan PAPOFA lepa menunjukkan penggembangan tinggi berbanding dengan mortar simen portland tulin. Empat kiub bersaiz 100 mm diuji pada kekuatan mampatan dan purata dilaporkan. Keputusan menunjukkan semua konkrit kecuali BIPOFA, MAPOFA dan KTPOFA mencapai kekuatan mampatan melebihi 41 MPa yang mana memerlukan konkrit kekuatan tinggi bagi setiap ACI 363. Kualiti semua konkrit mengandungi POFA daripada sumber berbeza kecuali MAPOFA menunjukkan peningkatan dalam tempoh rintangan klorida. .

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LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ASTM	American Society of Testing of Materials
C_2S	Dicalcium Silicate
C_3A	Tricalcium Aluminate
C_3S	Tricalcium Silicate
C-A-H	Calcium Aluminate Hydrate
C-S-H	Calcium Silicate Hydrate
CaO	Calcium Oxide
LOI	Loss On Ignition
MgO	Magnesium Oxide
OPC	Ordinary Portland Cement
POFA	Palm Oil Fuel Ash
SiO_2	Silicon dioxide
SO_3	Sulphur Oxide
RCPT	Rapid Chloride Pentration Test

CHAPTER 1

INTRODUCTION

1.1 Introduction

Recently, the construction industry is becoming large day by day; therefore, the demand to produce good industrial materials to construct tall buildings and very big projects is required. High strength concrete (HSC) was developed as a good solution to construct tall buildings in 1970s, it is in general, cement-based concrete which meets special performance and strength requirements with regards to workability, strength, and durability, that cannot always be obtained with techniques and materials adopted for producing conventional cement concrete. On the other hand, HSC using cement alone as a binder requires high paste volume, which often leads to excessive shrinkage and large evolution of heat of hydration, besides increasing the cost, therefore, many attempts in cement industry have been developed to reduce the cost of production of Portland cement, to reduce the consumption of the raw materials, to enhance the quality of concrete and to introduce the new materials to partially replace the cement which is the most expensive constituent in concrete.

Pozzolanic materials have been successfully used as supplementary cementing materials to produce high strength concrete (HSC) that is able to stand against the external attacks such as chloride attacks and acidic beside internal degradations such as internal chloride ions and alkali aggregate reaction (AAR).

Recently, silica fume, fly ash and blast furnace slag are some of by-product pozzolanic materials which are available in markets to replace cement with different percentage depend on their chemical and physical compositions.

Many researchers have studied the use of agrowaste and by product materials such as silica fume and rice husk ash (Mehta, 1979; Mehta, 1983; Mehta, 1986; Mehta, 1992; Alum, 1992), sawdust ash (Udoeyo and Dashibil, 2002), bagasse ash (Singh et al., 2000) and palm oil fuel ash (Tay, 1990; Hussin and Awal, 1996). Their results have revealed that these growaste materials possessing a good amount of silica and could be used as pozzolanic materials.

1.2 Introduction to high strength concrete

The methods and technology for producing HSC are not basically different from those required for concrete of normal grade except that the emphasis on quality control is perhaps greater with HSC. HSC can be produced with all of the cements and cement replacements normally available in Malaysia, including Portland cement, sulfate-resisting Portland cement, and combinations with pulverised fuel ash and ground granulated blast furnace, silica fume slag. High early strength cements should preferably be avoided as a rapid rise in hydration temperature may cause problems of (internal) cracks or micro-cracks due to the higher cementitious material content.

HSC can be produced with a wide range of aggregates, but smooth and/or rounded aggregates may tend to exhibit aggregate bond failure at a relatively low strength.

Crushed rock aggregates, of 10 to 20 mm size which are not too angular and elongated, should preferably be used. However, it has been found that bond strength between smaller size aggregates is greater than between larger size aggregates and for that reason smaller size aggregates (10 to 17 mm) tend to give better results. Fine sands should be avoided, particularly those with high absorption.

Superplasticisers should be used to achieve maximum water reduction, although plasticisers may be adequate for lower strength HSC (C60 to C70). Silica fume (microsilica) can be used to enhance the strength at high levels. To facilitate handling, silica fume is often blended into a slurry with superplasticisers, or supplied as a densified powder.

The basic proportioning of an HSC mix follows the same method as for normal strength concrete, with the objective of producing a cohesive mix with minimum voids. This can be done by theoretical calculations or subjective laboratory trials.

The basic strength to water/cement ratio relationships used for producing normal strength concrete are equally valid when applied to HSC, except that the target water/cement ratio can be in the range 0.30-0.35 or even lower. It is essential to ensure full compaction at these levels. A higher ultimate strength can be obtained by designing a mix with a low initial strength gain and cementitious additions. This is partially due to avoidance of micro-cracking associated with high thermal gradients. This effect can be facilitated if strength compliance is measured at 56 instead of 28 days. Increasing the cement content may not always produce higher strength. Above certain levels it may have little effect. An optimum amount of total cementitious material usually appears to be between 450 and 550 kg/m^3.

HSC mixes tend to be very cohesive and a concrete with a measured slump of 50 mm may be difficult to place. As HSC is likely to be used in heavily reinforced sections, a higher workability, should be specified if honeycombing is to be avoided.

When superplasticisers are used, concrete tends to lose workability rapidly. HSC containing such materials must therefore be transported, placed and finished before they lose their effect. Many modern superplasticisers can retain reasonable workability for a period of about 100 minutes, but care is still needed, particularly on projects where ready-mixed concrete delivery trucks have long journey times. Often, in order to avoid drastic decreases in slump and resultant difficulty in placing, superplasticisers are only partly mixed on batching, the balance being added on site prior to pouring.

The same production and quality control techniques for normal strength concrete should also be applied to HSC. For HSC the importance of strict control over material quality as well as over the production and execution processes cannot be over-emphasized. In general, production control should include not only correct batching and mixing of ingredients, but also regular inspection and checking of the production equipment, e.g. the weighing and gauging equipment, mixers and control apparatus. With ready-mixed concrete supply, this control should extend to transport and delivery conditions as well.

The main activities for controlling quality on site are placing, compaction, curing and surface finishing. Site experience indicates that more compaction is normally needed for high strength concrete with high workability than for normal strength concrete of similar slump. As the loss in workability is more rapid, prompt finishing also becomes essential. Particular attention needs to be given to vibration at boundaries of individual loads to avoid 'pour lines'. To avoid plastic shrinkage, the finished concrete surface needs to be covered rapidly with water-retaining curing agents. As the quality of the structure with HSC is the main objective, it is essential that, in addition to the above, the accuracy of the formwork and the fixing details of the reinforcement and/or prestressing steel should also form part of the control activities. It is also desirable to assess the in-situ strength of the concrete in the actual structure by some nondestructive methods (such as hammer tests or ultrasonic pulse velocity measurements) for comparison with compliance cube test results, to establish that no significant difference exists between the two sets of results. It should be borne in mind that factors which have only a second-order effect at lower strength levels may become of major importance at higher levels.

1.3 Problem statement

As mentioned above, it is possible to produce high strength concrete by using a large amount of cement but this way will lead to many durability problems such as excessive shrinkage and large evolution of heat of hydration. Therefore; in this study palm oil fuel ash will be used as cementing replacement materials to produce high strength and durable concrete.

Cement and water are the most important constituents that can affect strength and durability of concrete, therefore, good quality concrete can be obtained if optimum amounts of these constituents are used in mix design.

Significantly, content and type of cement have large effects on durability of concrete, large amount of cement may lead to cracks due to concrete shrinkage that is sufficient to allow harmful ions to ingress causing deterioration of concrete.

However, pozzolanic materials are used to partially replace cement in mixtures to improve the quality of concrete against the external attacks and internal degradation.

1.4 Palm Oil Fuel Ash

At present, some 200 palm oil mills are in operation in Malaysia. Malaysia currently accounts for 41 % of world palm oil production and 47% of world exports, and also for 11% and 25% of the world's total production and exports of oils and fats respectively. As a consequence of this big palm oil industry, there are approx. 20 tonnes of nut shells, 7 tonnes of fibers, and 25 tonnes of empty bunches discharged from the mill for every 100 tonnes of fresh fruit bunches processed.

These waste materials are burnt at temperatures of about 800–1000 °C. 5% of ash is produced and then disposed of in landfill causing environmental pollution and degradation.

The ash being light and of small particle size, is easily carried away by wind resulting in smog on a humid day. The smog reduces visibility and creates traffic hazard besides being a potential health hazard leading to bronchi and lung diseases. In addition, the ash does not have sufficient nutrients to be used as fertilizer (Tay and Show, 1995).

As a solution to the disposal problem of the ash derived from palm oil, research studies have been carried out to examine the feasibility of using the ash as cement replacement materials. They have found that Palm oil fuel ash is reactive pozzolanic materials and can be used in making high-strength concrete (Tay, 1990;

Hussin and Awal, 1996; Vanchai et al., 2007; Chindaprasirt et al., 2008; Budiea, 2008 and Weerachart et al., 2009).

1.5 Objectives and Scope of Research

The main aim of this study is to investigate the potential of producing high strength concrete using Portland cement containing POFA from different sources as replacement materials and its effects on durability.

According to incineration condition and feeding materials (fruit bunches, fibers and shells) in biomass thermal power plants, quality of produced POFA is varies, as a result; quality of concrete will be varies.

The following objectives are identified to satisfy this aim:

- To investigate POFA from different sources in Malaysia as replacement cementing materials to produce high strength concrete;
- To develop fundamental criterions governing POFA from different sources in Malaysia according to its sources;
- To investigate compressive strength of high strength concrete containing POFA from various sources;
- To investigate chloride resistance of high strength concrete containing POFA from various sources.
- To investigate sulfate resistance of high strength concrete containing POFA from various sources.

Compressive strength, chloride resistance and sulfate resistance are examined to investigate durability of high strength concrete containing 20% POFA with fineness of 45 μm from different sources in Malaysia.

1.5 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.