EFFECTS OF PALM [illegible] CRETE TOWARDS CHLORIDE RESISTANCE

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ABSTRACT

Nowadays, high durability concrete and environmental friendly approach toward building, structure and other concrete construction is in demand. The used of Portland cement also increase CO_2 to environment. In other hand, there are also issues on excess side product from palm oil production which is palm oil fuel ash (POFA) which also can contribute to environmental problem. POFA is a waste consist of fibers, shells and empty fruit bunches being incinerate. POFA need to be fully utilized in more benefit ways and since properties of POFA slightly the same with Portland cement, this give an idea to use it as replacement of cement. Besides that, composition of POFA could resist toward chloride reaction. So, by using POFA as replacement for Portland cement, it expected that there will be reduction of CO_2 and excess POFA in our environment and more durability concrete can be produced. Chloride ingression inside the concrete structure and cause steel structure and rebar to become rust and weaken the structure as a whole. In this research, there will be test on chloride resistance and porosity as indicator of chloride ingression towards the concrete. Preparation of sample including batching, mixing and casting was earlier prepared before testing being conduct. 24 cubical concrete samples and 24 cylindrical concrete samples being prepared and cured for 28 days. Chloride resistance test including salt ponding, open circuit potential (OCP) and impress voltage while porosity test involving vacuum saturation method. Result from this test will be indicator of POFA effectiveness towards chloride resistance.

ABSTRAK

Kini, konkrit berketahanan tinggi dan penggunaan kaedah mesra alam untuk penghasilan konkrit untuk struktur bangunan mendapat permintaan yang tinggi. Penggunaan simen Portland semakin meningkat turut mempengaruhi peningkatan pengeluaran CO_2 ke alam sekitar. Selain itu, isu produk sampingan yang berlebihan daripada pengeluaran minyak kelapa sawit iaitu abu bahan api minyak sawit (POFA) juga boleh menyumbang kepada masalah alam sekitar. POFA adalah hasil pembakaran sisa daripada gentian, cengkerang dan tandan. POFA boleh digunakan sebagai alternatif dalam penghasilan konkrit kerana kandungan POFA mempunyai persamaan yang hampir sama dengan simen Portland. Ini merupakan alternatif sebagai pengganti simen dan komposisi POFA dapat menahan kesan ion klorida. Ini dapat mengurangkan penghasilan CO_2 yang berlebihan kepada persekitaran kita dan menghasilkan konkrit yang lebih berketahanan tinggi. Kemasukan ion klorida di dalam struktur konkrit menyebabkan keluli dan rebar menjadi karat dan melemahkan struktur secara keseluruhan. Dalam kajian ini, beberapa ujian ke atas ketahanan klorida dan keliangan konkrit dijalankan. Penyediaan sampel termasuk campuran konkrit dan pembentukan dilakukan sebelum ujian. 24 sampel konkrit berbentuk kubus dan 24 sampel konkrit berbentuk silinder disediakan dan diawet selama 28 hari. Ujian terhadap kesan ion kloroda termasuk ujian rintangan dalam air garam (salt ponding), ujian potensi dalam litar terbuka (OCP) dan kesan voltan manakala ujian keliangan yang melibatkan kaedah vakum tepu. Keputusan daripada ujian ini akan menjadi penentu keberkesanan POFA terhadap kesan klorida.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

POFA	Palm Oil Fuel Ash
OPC	Ordinary Portland cement
OCP	Open circuit potential

CHAPTER 1

INTRODUCTION

1.1 Background of study

Malaysia is one of largest palm oil's producers which conquered about 39 percent of world palm oil production and 44 percent of world export. Currently, 4.49 million hectares of land in Malaysia is under palm cultivation which estimated producing 17.73 million tons of palm oil according to statistic from Malaysian Palm Oil Board (MPOB). In palm oil production, there are also side product and solid waste materials that being produced. Solid waste materials is in the form of fibers, shells, and empty fruit bunches which mostly being incinerate until become an ash that call palm oil fuel ash (POFA). POFA can contribute to an environmental pollution once it unmanageable, so utilization of POFA required in achieving zero emission of palm oil production and save our world from being polluted.

As a solution to the disposal problem of the ash derived from oil-palm shells, fibers, and bunches, research studies have been carried out to examine the feasibility of using the ash as cement replacement materials. Previous researchers (Tay, 1990; Awal and Hussin, 1996; Awal and Hussin, 1997; Sukuntapree et al., 2002) found that POFA

had pozzolanic properties and could be used as a replacement of Portland cement in concrete.

Chemically, POFA is one of the agro-waste consist of high percentage of silica and this will be high advantage as alternative replacement or reducing consumption of Portland cement (Tangchirapat et al., 2003). Portland cement normally used for concrete in civil structure especially in building construction.

Research was being done and focusing on reducing the consumption of Portland cement by using POFA as additional mixture in concrete production rather than replace it totally. There are many researches which concentrate on different ratio of POFA and Portland cement and test on durability, strength, corrosion effect and other related to normal concrete being conduct in order to get the best combination that meets standard requirement of concrete. In most of research, usage of POFA as a concrete mixture improved the corrosion effect from chloride and sulphide to steel structure in concrete (Saleh Bamaga et al., 2011).

This will be very promising result for civil engineering field in term of reducing consumption of Portland cement that directly reduce cost of project and also improve quality of concrete to be more resistance to corrosion effect. This also give added advantage to preserve good and healthy environment in general because POFA being manageable in better way.

1.2 Problem statement

In Malaysia, palm oil industry is one of biggest sector of industry in Malaysia. Demand of palm oil in world market are keeping increasing every years and proportionally contribute to increasing of palm oil fuel ash (POFA). POFA is by-product produce from incineration of fibers, shells, and empty fruit bunches. Unfortunately most of the POFA were disposed as a waste in landfill which causing environmental problem if not fully utilize to alternative used.

In other hand, construction and development project required usage of high amount of concrete. The main raw material for conrete is portland cement. The production of portland cement release carbon dioxide to environment because this cement was produce from combustion of lime either using the coal or petrol as a fuel. CO_2 could pollute our environment and cause greenhouse effect especially when high amount of concrete being produce. In another perspective, since the demand of concrete was high, there also a consideration on high resistance concrete ability towards chloride resistance which really important and vital to preserve building and structure to be durable towards environmental effect.

As previous research, POFA contains high silica and low pozzolanic properties which slightly similar to Portland cement. POFA might have edge advantage in order to give concrete either with similar resistance towards chloride or even better which research needs to be carrying out. This will become massive findings in order to replace high used of Portland cement which can pollute environment as well as high resistance concrete towards chloride.

1.3 Objectives

The main objective of this research is to study on the chloride resistance of concrete with POFA as a replacement material. By referring the main objective, other objectives are to be determined as below:

1. To find optimum POFA as cement replacement in concrete.
2. To determine the effect of POFA as cement replacement towards chloride resistance.
3. To determine the effect of POFA as cement replacement towards concrete porosity.

1.4 Scope of study

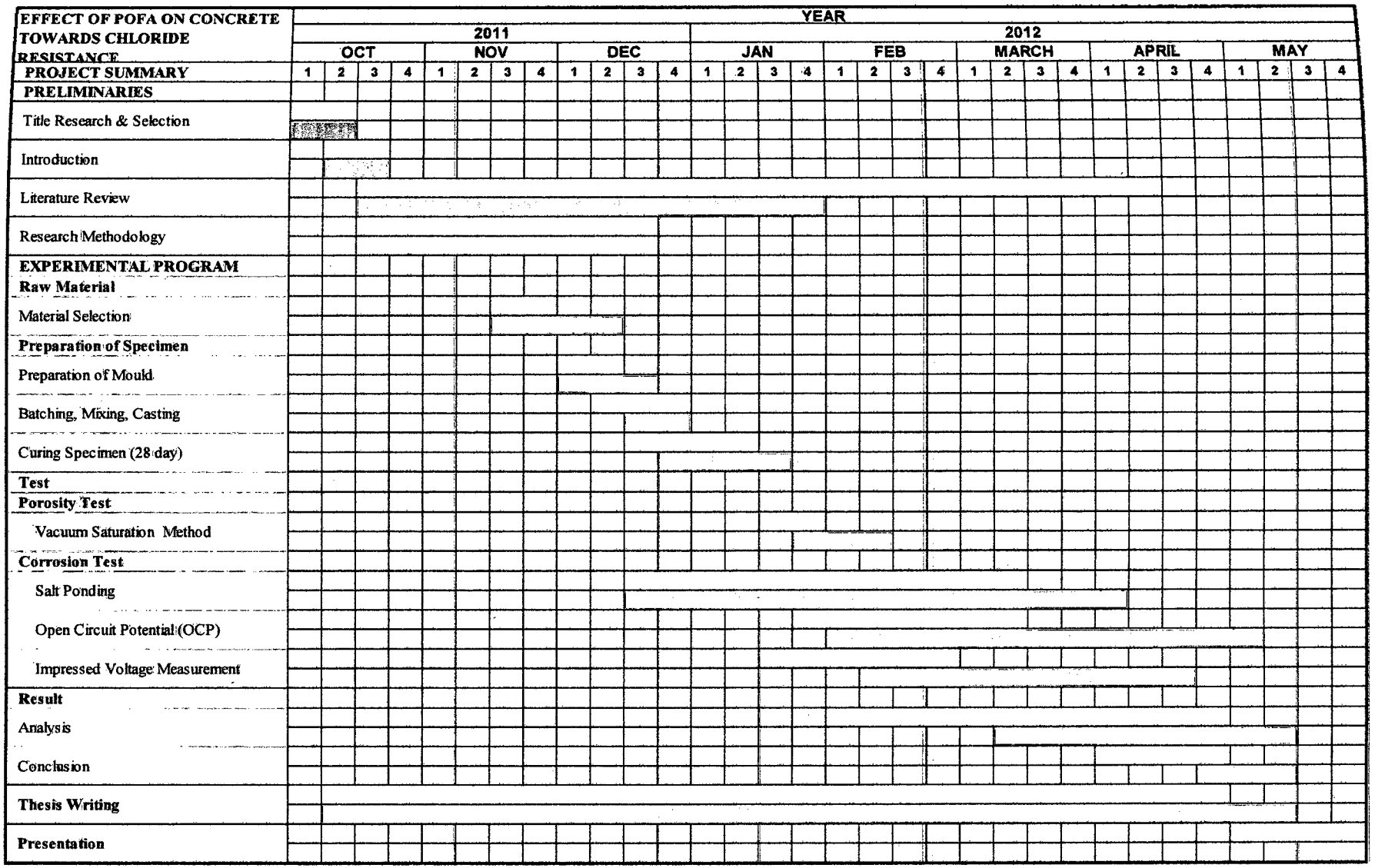
The main scope of this research is to study on POFA as cement replacement for concrete and effect towards chloride resistance. The scope of study also including as below:

1. Focusing on chloride attack in concrete structure.
2. The mixtures of modified concrete are only using palm oil fuel ash (POFA) as a partial replacement in cement content.
3. Test on different sample that consist of control sample, 10 %, 20% and 30% of POFA.
4. Samples were cured in water for 28 days.
5. The samples were tested on the Open Circuit Potential (OPC), Salt Ponding, Impress Voltage and Vacuum Saturation.
6. Test is complete at FKASA laboratory, UMP.

1.5 Significant of study

This study expected to give clearer view on the effectiveness of concrete with POFA towards chloride resistance. POFA highly rated as one of material to replace current Portland cement due to its chemical and physical composition which is slightly similar to Portland cement. This study could be a stepping stone to find right ratio of POFA in concrete structure to resist towards chloride resistance. In other hand, the success of this study will be contributed to promote POFA as best alternative for concrete mixture and the reduction of Portland cement used will be a massive solution to preserve good environment.

1.6 Gantt chart



CHAPTER 2

LITERATURE REVIEW

2.1 Concrete

Concrete is a composite construction material which composed of cement that commonly used Portland cement and other cementations materials such as fly ash and slag cement, aggregate generally a coarse aggregate made of gravel or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand, water and chemical admixtures. Communities around the world rely on concrete as a safe, strong and simple building material. Concrete widely used in construction of building and facilities including domestic, commercial, recreational, rural and educational construction. Nowadays, there are more concern in designing the high quality concrete, strong and durable which in same time preserve environment especially in term of material usage.

Generally, concrete has relatively high compressive strength but has much lower tensile strength. This is because concrete usually reinforced by steel which stronger in tension and give tensile strength towards concrete. The elasticity of concrete

is relatively constant at low stress levels but a start decreasing at higher stress levels as matrix cracking develops. Concrete has a very low coefficient of thermal expansion and shrinks as it matures. At some extent, concrete structures will crack due to shrinkage and tension while exposure to long-duration forces will cause concrete to deformation.
There have three types of concrete where normally use in construction such as:

i) Reinforced concrete

Concrete strengthened by the inclusion of metal bars, which increase the tensile strength of concrete. Both unreinforced and reinforced concrete can be either cast in place or precast.

ii) Cast-in-place concrete

Poured onsite into a previously erected form that is removed after the concrete has set. Lighthouses are typically constructed using cast-in-place construction methods.

iii) Precast concrete

Molded offsite and bring to building components. This method of construction is seldom used for lighthouses. Precast concrete normally used at mega project and bridge construction.

2.2 Cement

Cement is main material in concrete design and construction. Cement can be defined as the bonding material that has cohesive & adhesive properties which makes it capable as basic material for concrete construction. Ordinary/Normal Portland cement is one of the most widely used types of Portland cement. Generally, Portland cement has a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulfate (which controls the set time) and up to 5% minor.

The chief chemical components of ordinary Portland cement are such as Calcium, Silica, Alumina and Iron. Calcium is usually derived from limestone, marl or chalk while silica, alumina and iron come from the sands, clays & iron ores. Other raw materials may include shale, shells and industrial byproducts (Muhammad Sohail). Basic component of Portland cement are shown in Table 2.1 and Table 2.2 below.

Table 2.1: Basic component of Portland cement (Muhammad Sohail)

Contents	Percent (%)
CaO	60 – 67
SiO_2	17 – 25
Al_2O_3	3 – 8
Fe_2O_3	0.5 – 6.0
MgO	0.5 – 4.0
Alkalis	0.3 – 1.2
SO_3	2.0 – 3.5

Table 2.2: Main Constituents in a Typical Portland Cement (Mindess and Young, 1981)

Chemical Name	Chemical Formula	Shorthand Notation	Percent by Weight
Tricalcium Silicate	$3CaOSiO_2$	C_3S	50
Dicalcium Silicate	$2CaOSiO_2$	C_2S	25
Tricalcium Aluminate	$3CaOAl_2O_3$	C_3A	12
Tetracalcium Aluminoferrite	$4CaOAl_2O_3Fe_2O_3$	C_4AF	8
Gypsum	$CaSO_4H_2O$	CSH_2	3.5

Different types of Portland cement are manufactured to meet different physical and chemical requirements for specific purposes, such as durability and high-early strength. Eight types of cement are covered in ASTM C 150 and AASHTO M 85. These types and brief descriptions of their uses are listed in Table 2.3 below:

Table 2.3: Types of Portland cement and area used.

Cement type	Use
I[1]	General purpose cement, when there are no extenuating conditions
II[2]	Aids in providing moderate resistance to sulfate attack
III	When high-early strength is required
IV[3]	When a low heat of hydration is desired (in massive structures)
V[4]	When high sulfate resistance is required
IA[4]	A type I cement containing an integral air-entraining agent
IIA[4]	A type II cement containing an integral air-entraining agent
IIIA[4]	A type III cement containing an integral air-entraining agent

Notes:

1. Cements that simultaneously meet requirements of Type I and Type II are also widely available.
2. Type II low alkali (total alkali as $Na_2O < 0.6\%$) is often specified in regions where aggregates susceptible to alkali-silica reactivity are employed.
3. Type IV cements is only available on special request.
4. These cements are in limited production and not widely available.

Cement is defined chemical entity formed from predetermined ratios of reactants at a fairly precise temperature. Ordinary Portland cement results from the calcinations of limestone and silica in flowing reaction

Limestone + silica (1450 °C) = Portland cement + Carbon dioxide

$5\ CaCO_3 + 2SiO_2 = (3CaO, SiO_2)\ (2CaO, SiO_2) + 5CO_2$

The production of 1 tons of cement produces 0.55 tons of chemical CO_2 in a reaction that takes place at 1450 °C. An additional 0.4 tones of CO_2 is given off as result of the burning of carbon fuel to provide this heat (Davidovits,J.)

2.3 Palm Oil Fuel Ash (POFA)

Palm oil fuel ash is by product produced from mass production of palm oil. POFA form from incineration of palm oil solid waste such as empty bunches fiber and shell. POFA can be use source to generate electricity at certain oleochemical industry. However, the increasing in palm oil production yearly cause the excess existent of POFA while demand to generate electricity is not as much as being produced. Unmanageable of POFA will pollute the environment and also cause serious damage to inhalation system either to human or animal.

Therefore, utilization of POFA for other application that environmental friendly were required instead of discharge to landfill or use as a fuel. So far, there was discovery to use POFA as partial cement replacement in concrete structure at it was limited to production of normal concrete (Hussin and Abdul Awal 1996)and high strength concrete (Sata et al. 2004). Roughly, POFA consist of high silica content and low pozzolanic properties due to large particle and porous structure which would be ideal replacement for Portland cement (Tangchirapat et al., 2003). Pozzolanic properties in POFA also increase strength and durable concrete towards chloride and sulphate attack (Awal, 1997).

2.4 POFA as cement replacement material

POFA was highly rated as potential cement replacement and will minimize the effect to environment due to excess disposal either to landfill or direct towards environment (Salihuddin and Hussin, 1993). In early research, there are findings shows that partial replacement of POFA by 30% weight of cement manage to achieve the strength and durability aspects of plain concrete that using Portland cement (Abdul Awal and Hussin, 1997). Researcher also claimed that partial replacement of POFA also improved the normal concrete in term of strength and durability due to pozzolanic materials of this fly ash (Sivasundaram and Alexander, 1999). Pozzolanic materials cause reaction which large particle of fly ash physically because refinement of pore structures and resulting the structure of concrete become highly impermeable and denser than original. It gives more compressive strength and durability to the concrete (Feldman, 1990). Researcher also believe that POFA will effect to the internal structure of concrete and will be subject to further investigation which they believe this could be massive discovery of real ability of POFA as replacement for Portland cement (Mohd Warid Hussin, Khairunisa Muthusamy and Fadhadli Zakaria, 2010) POFA also has high silica content, SiO2, which chemically quite similar to current Portland cement give it as one of the best option to replace the used of Portland cement (Hussin MW and Tangchirapat, 2007).

The particle size distributions of materials are shown in Figure 2.1. It was found that OP (original size POFA) had large particles with a median particle size of 183μm and most particles were rather of porous texture (Figure 2.1 (a)). After POFA was sieved, MP (medium particle sizes - 15.9μm) and SP (small particle sizes - 7.4μm) had particles with irregular and crushed shapes (Figure 2.1 (b) and (c)), and the median particle sizes were reduced to 15.9μm and 7.4μm, respectively

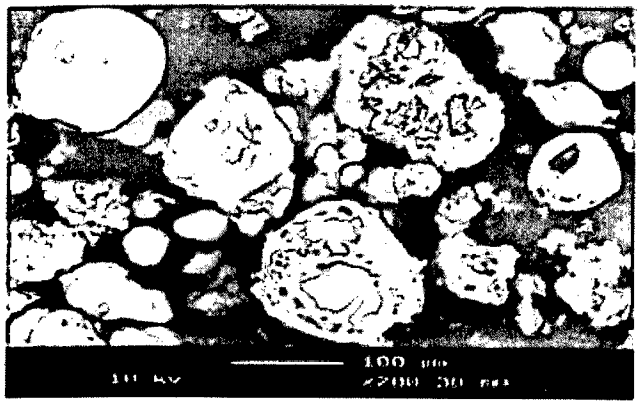


Figure 2.1 (a): Original size palm oil fuel ash (OP)

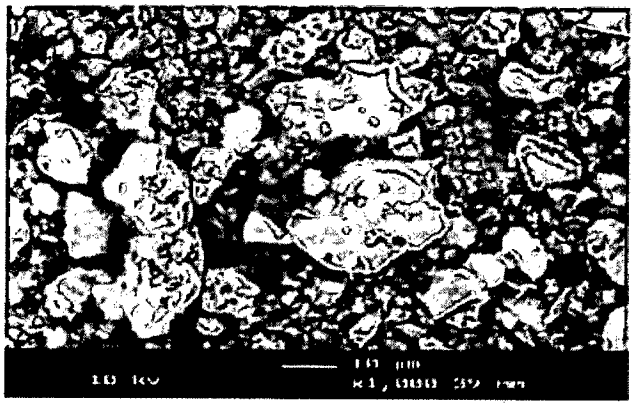


Figure 2.1 (b): Medium size palm oil fuel ash (MP)

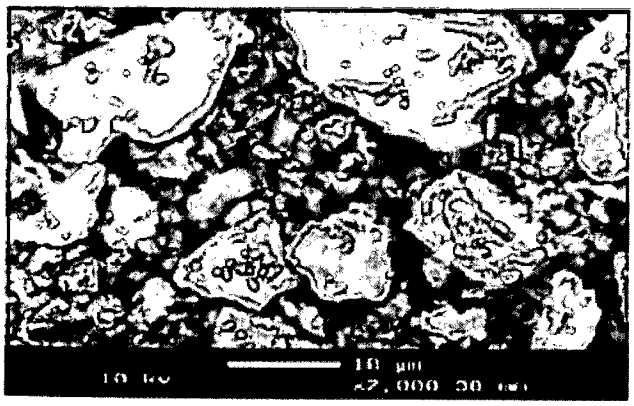


Figure 2.1 (c): Small size of palm oil fuel ash (SP)

Figure 2.1 (a), (b), (c): Scanning electron microscopy of palm oil fuel ash.

The physical properties of POFA are shown in Table 2.4 and the chemical composition of POFA is shown in Table 2.5

Table 2.4: Physical properties of OPC and palm oil fuel ash

Physical properties	**OPC**	**POFA**
Specific gravity	3.15	2.18
Retained on sieve number 325 (%)	—	1
BET surface area (m2 /g)	4.75	14.4

Table 2.5: Chemical constituents of OPC and palm oil fuel ash

Chemical constituents (%)	**OPC**	**POFA**
Silicon dioxide (SiO_2)	28.2	53.82
Aluminum oxide (AL_2O_3)	4.9	5.66
Ferric oxide (Fe_2O_3)	2.5	4.54
Calcium oxide (CaO)	50.4	4.24
Magnesium oxide (MgO)	3.1	3.19
Sodium oxide (Na_2O)	0.2	0.1
Potassium oxide (K_2O)	0.4	4.47
Sulfur oxide (SO_3)	2.3	2.25
Phosphorus oxide (P_2O_2)	< 0.9	3.01
LOI	2.4	10.49

2.5 Pozzolanic reaction

Pozzolan material influence the usage of cement because high pozzolan concrete will required less cement to obtain specified strength. The amount of cement reduction will vary depending upon the reactivity of the pozzolan. Pozzolan material with high