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PROPERTIES OF CONCRETE CONTAINING POFA WITH DIFFERENT FINENESS AS PARTIAL SAND REPLACEMENT

NUR AZZIMAH BINTI ZAMRI

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Civil Engineering.

Signature:
Name of Supervisor: Khairunisa Binti Muthusamy
Date: 19 June 2012

Signature:
Name of Co-Supervisor: Fadzil Bin Mat Yahaya
Date: 19 June 2012

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Name: Nur Azzimah Binti Zamri

ID Number: AA08079

Date: 19 June 2012

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ABSTRACT

Malaysia is the world largest exporters of palm oil which the industry has brought enormous revenue to our country. However, palm oil fuel ash which is a by product from palm oil mill that has been dumped at landfill thus causing environmental pollution. It is seen that incorporation this waste in concrete production would be able to reduce amount of waste disposed at landfill. This investigation focus on the effect of POFA fineness on the workability, compressive strength and moisture absorption of concrete. Plain concrete is used as control specimen. Another type is concrete mix containing POFA of different fineness which replace 10 % POFA of sand by weight. The POFA was sieve into several of fineness that are POFA passing 300 μm, POFA passing 600 μm, POFA passing 1.18 mm and POFA originally taken from palm oil mill. The results revealed that the workability is the highest when using smallest particle of POFA that is POFA passing 300 μm. For compressive strength, it shows that POFA concrete are much lower than that of concrete without POFA. Mix containing POFA passing 300 μm recorded highest in strength compare to those POFA concretes at 28 days. In the case of water absorption, POFA passing 1.18 mm recorded the highest water absorption compare to other POFA concretes. Thus, it is recommended that POFA passing 300 μm can be added as partial sand replacement to produce concrete.

ABSTRAK

Malaysia merupakan antara pengeluar minyak kelapa sawit terbesar di dunia. Pengeluaran minyak dalam kuantiti yang semakin banyak ini telah menyebabkan penjanaan sisa buangan terutamanya abu kelapa sawit (POFA) turut meningkat. Sisa ini telah dibuang di tapak pelupusan sehingga menyebabkan pencemaran alam sekitar. Antara kaedah yang berpotensi mengurangkan jumlah sisa kelapa sawit ialah penggunaan bahan buangan ini dalam pembuatan konkrit. Kajian ini bertujuan menyelidik kesan penggunaan abu kelapa sawit yang berlainan saiz sebagai bahan separa pengganti pasir dalam pembuatan konkrit. Antara sifat-sifat konkrit yang dikaji adalah kebolehkerjaan, kekuatan mampatan serta kebolehserapan air. Konkrit kosong tanpa sebarang modifikasi telah dijadikan sebagai konkrit kawalan. Bagi konkrit yang diubahsuai pula, 10 % daripada berat pasir digantikan dengan abu kelapa sawit yang memiliki saiz yang berlainan. Debu kelapa sawit ini diayak kepada pelbagai darjah kehalusan iaitu abu kelapa sawit melepasi 300 μm, abu kelapa sawit melepasi 600 μm, abu kelapa sawit melepasi 1.18 mm dan abu kelapa sawit tanpa sebarang ayakan. Keputusan menunjukkan bahawa darjah kebolehkerjaan konkrit adalah paling baik apabila menggunakan abu kelapa sawit yang mempunyai saiz paling halus. Kekuatan mampatan konkrit menggunakan abu kelapa sawit pula lebih rendah berbanding dengan konkrit biasa pada hari yang ke 28. Dalam ujian keserapan air pula, konkrit menggunakan debu kelapa sawit melepasi 1.18 mm menunjukkan darjah keserapan yang tertinggi. Justeru itu, abu kelapa sawit melepasi 300 μm adalah dicadangkan sebagai bahan separa untuk menggantikan pasir dalam konkrit.

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LIST OF SYMBOLS

s	Second
%	Percent
°C	Degree Celcius
MPa	Megapascal
kg/m^3	Kilogram per cubic meter
μm	Micrometer
mm	Milimeter

LIST OF ABBREVIATIONS

ASTM	American Standard Testing
$Ca(OH)_2$	Calcium Hydroxide
C_3A	Tricalcium Aluminate
C_4AF	Tetracalcium Aluminoferrite
C-S-H	Calcium Silicate Hydrate
CSH_2	Gypsum
C_2S	Dicalcium Silicate
C_3S	Tricalcium Silicate
MS	Malaysian Standard
OPC	Ordinary Portland cement
POFA	Palm oil fuel ash
SiO_2	Silica
YTL	Yeoh Teong Lay

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Malaysia is focusing on bio-technology industry aimed to produce better and quality agriculture products and palm oil is listed as one of the main commodities to be exported internationally. Palm oil accounts for 20% and 46% of the global oil and fats production and trade respectively. Malaysia is the world's largest producer and exporter of palm oil with a 50% share of world palm oil production and 61% of exports (Khoo and Chandramohan, 2002). Thus, it is expected that millions tons of palm oil waste will be produced annually due to its productivity. Resulting from the huge amounts of waste known as palm oil fuel ash (POFA) generated from this industry, the government needs to allocate more hectares of landfill for disposal and spends a lot of money for transporting the waste and also maintenance purposes. However, effect taken to recycle the waste material can reduce the dumped waste as well as to ensure environment sustainability.

Since the issues related to environmental conservation has gained great importance in our society in recent years (Xue, 2009), the decision-makers in political, economic, and social sectors are now seriously offering more attention to the environment issues. Consequently, major changes regarding the conservation of resources and recycling of wastes by proper management are taking place in our ways of living and working. Many authorities are working to have the privilege of reusing the wastes in environmentally and economically sustainable ways (Aubert, 2006). The utilization of wastes in construction materials is one of such innovative effort.

At the same time, increase in the use of concrete in the developing construction industry has led towards high demand of natural aggregates for concrete production. This may lead to depletion of natural aggregates as well as cause ecological imbalance. Thus, the use of alternative constituents such as waste material to partial aggregates replacement would be able to reduce usage of natural aggregates and create environmental friendly building material. The present study investigates the potential use of palm oil fuel ash from palm oil industry which is a waste in the production of concrete material.

1.2 PROBLEM STATEMENT

Growth of population, increasing urbanization and rising standards of living due to technological innovations have contributed towards increasing the quantity of a variety of solid wastes generated by industrial, mining, domestic and agricultural activities. As Malaysia is one of the largest palm oil producers, a large amount of waste known as palm oil fuel ash (POFA) from palm oil mill has been produced and dumped as profitless waste. This results in environmental problem and also increases the cost of waste management by palm oil industries. At the same time, the cost of construction material is increasing due to high demand and scarcity of raw material. Sand is one of the natural resources which continue to deplete due to its utilization in concrete manufacturing industry. Therefore, it is seen that integrating POFA as partial sand replacement would be one of the steps to reduce the use of natural sand in concrete production. At the same time, this approach would reduce the amount of POFA ending up at landfill and also assist at the palm oil industry to be more environmental friendly.

1.3 OBJECTIVE

The objectives of the research are as follows:

i. To study the effect of POFA fineness towards workability of concrete containing POFA as partial sand replacement.

ii. To determine the effect of POFA fineness towards density and compressive strength of concrete containing POFA as partial sand replacement.

iii. To study the effect of POFA fineness towards water absorption of concrete containing POFA as partial sand replacement.

1.4 SCOPE OF STUDY

This study concentrates on investigation of workability, compressive strength, and water absorption of concrete material made by integrating palm oil fuel ash (POFA) as partial sand replacement. Two types of mix have been used in this study that is plain concrete and concrete containing palm oil fuel ash (POFA) of various fineness. Plain concrete produced using natural aggregates serves as control specimen. Four types of POFA concrete are made using different fineness of POFA that is POFA passing 300 µm, POFA passing 600 µm, POFA passing 1.18 mm and POFA originally taken from palm oil mill.

In order to study the effect of POFA fineness towards workability, all the mixes including control specimen were subjected to slump test, compacting factor test and Vebe test. The influence of POFA fineness to compressive strength performance of hardened concrete were investigated by producing cubes using the mixes before subjected to water curing for 28 days prior to compressive strength testing. Finally, the influence of POFA towards water absorption of concrete is determined by carrying out water absorption test on cubes produced using mixes containing various fineness of POFA. All the experiment conducted in this study is in accordance to the existing standard.

1.5 SIGNIFICANT OF RESEARCH

Findings from this study would provide information on the influence of POFA fineness towards workability, compressive strength and water absorption properties of concrete. Use of POFA as partial sand replacement in concrete would be able to contribute towards preservation of natural sand for future generation and at the same time assist the palm oil industry to be more environmental friendly.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Concrete is a man-made composite and the major constituent of which is natural aggregate, such as gravel and sand and crushed rock (Jackson, 1996). It is widely used in domestic, commercial, recreational, rural and educational construction. Communities around the world rely on concrete as a safe, strong and simple building material. It is used in all types of construction, from domestic work to multi-storey office blocks and shopping complexes. Despite the common usage of concrete, people are aware of the considerations involved in designing strong, durable and high quality concrete. This material also can be produced by integrating suitable waste material as a mixing ingredient. One of the waste materials in Malaysia which has been added in concrete production is palm oil fuel ash (POFA), wastes generated from palm oil industry.

The global demand for palm oil is growing, thus prompting an increase in the global production particularly in Malaysia. Along with the increasing demand for palm oil, it is estimated that million tones of its waste will be produced yearly and Malaysian Government acquired to allocate more dumped area for disposal. Palm oil fuel ash (POFA) is also one of the wastage generated and contributes a huge percentage from the total wastage. Thus, the usage of POFA in concrete production will help to reduce the quantity of wastage at dumped area in our country.

2.2 NORMAL CONCRETE

According to Ravindra (1996), normal concrete has a comparatively low tensile strength and for structural applications, it is normal practice either to incorporate other materials inside it to resist compressive forces. It is also called normal weight concrete or normal strength concrete. In its simplest form, normal concrete is a mixture of paste and aggregates. The paste, composed of Portland cement and water, coats the surface of the fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete.

Concrete has many properties that make it a popular construction material. The correct proportion of ingredients, placement, and curing are needed in order for these properties to be optimal. However, concrete also have a disadvantage which is the concrete are inherently brittle material. On the other hand, concrete is also well known of its major problem associated with low tensile strength compared to compressive strength.

There have been many experimental work conducted by introducing a new material or recycled material as a replacement to aggregate or cement in concrete. This is done to produce environmental friendly construction materials with offer the stability and flexibility in designing all building structures.

2.3 INGREDIENTS FOR NORMAL CONCRETE

Normal concrete is the concrete in which common ingredients such as cement, coarse aggregate, sand and water. Carefully proportioning and mixing of the ingredients is the key to achieve a strong and durable concrete. A concrete mixture that does not have enough paste to fill all the voids between the aggregates will be difficult to place and will produce rough, honeycombed surfaces and porous concrete. A properly designed concrete mixture will possess the desired workability for the fresh concrete and the required durability and strength for the hardened concrete.

2.3.1 Sand

The fine aggregate shall consist of natural sand or, subject to approval, other inert materials with similar characteristics, or combinations having hard, strong, durable particles. In concrete mix, fine aggregate should comply with all types of grading requirements. When carrying out mixing process, the fine aggregate was saturated surface dry condition to ensure the water cement ratio is not affected. Fine aggregate for use in concrete that will be subject to wetting, extended exposure to humid atmosphere, or contact with moist ground shall not contain any materials that are deleteriously reactive with the alkalis in the cement in amount sufficient to cause excessive expansion of concrete.

Fine aggregates for concrete shall consist of natural screened and washed sand or crushed sand which having hard and durable particles, or of other inert materials with similar characteristics. It shall not contain harmful material such as clay lumps, tree roots, shale, iron pyrites, coal, mica, organic matter or any deleterious matter which may attack the reinforcement, in such a form or in sufficient quantity to affect adversely the strength and durability of the concrete. If necessary the aggregate shall be washed and sieved to remove the deleterious substances.

2.3.2 Coarse Aggregate

Aggregates used in concrete should be strong and hard as a stronger and harder aggregate will give a stronger final concrete. Graded aggregates should range in size so that they fit together well and gives a stronger and denser concrete. The shape and size of aggregate can affects the workability and strength of concrete. Rounded aggregates have lesser surface area and require lesser proportion of fine aggregate to get a cohesive mix. Angular aggregates make concrete harder to place, work and compact, but can make concrete stronger. Other than that, dirt or clay sticking to the aggregates will weaken the bond between paste and aggregates. Particle shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete.

Coarse aggregates can have round, angular, or irregular shape. Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded compact aggregate. Consequently, the cement content must also be increased to maintain the water-cement ratio. Generally, flat and elongated particles are avoided or are limited to about 15 percent by weight of the total aggregate. Unit-weight measures the volume that graded aggregate and the voids between them will occupy in concrete.

The void content between particles affects the amount of cement paste required for the mix. Angular aggregates increase the void content. Larger sizes of well-graded aggregate and improved grading decrease the void content. Absorption and surface moisture of aggregate are measured when selecting aggregate because the internal structure of aggregate is made up of solid material and voids that may or may not contain water. The amount of water in the concrete mixture must be adjusted to include the moisture conditions of the aggregate. Abrasion and skid resistance of an aggregate are essential when the aggregate is to be used in concrete constantly subject to abrasion as in heavy-duty floors or pavements. Different minerals in the aggregate wear and polish at different rates. Harder aggregate can be selected in highly abrasive conditions to minimize wear.

2.3.3 Cement

According to Dhir and Neil (1996), Portland cement is the most widely used in world, while the others are used where concretes with special properties are required. In this study we used Ordinary Portland Cement (OPC) for the binding process. It is highly durable and produces high compressive strengths in mortars and concretes. OPC is hydraulic cement that hardens by interacting with water and forms a water-resisting compound when it receives its final set. The addition of water to these minerals produces a paste which, when hardened will strength as stone. It is highly durable and produces high compressive strengths in concretes (Nawy, 1996). Portland cements can be characterized by their chemical composition although they rarely are for pavement applications. However, it is a Portland cement's chemical properties that determine its physical properties and how it cures. Table 2.1 shows the main chemical compound constituents of Portland cement.

Table 2.1: Main Constituents in a typical Portland Cement

Chemical Name	**Chemical Formula**	**Shorthand Notation**	**Percent by Weight**
Tricalcium Silicate	$3CaO.SiO_2$	C_3S	50
Dicalcium Silicate	$2CaO.SiO_2$	C_2S	25
Tricalcium Aluminate	$3CaO.Al_2O_3$	C_3A	12
Tetracalcium Aluminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF	8
Gypsum	$CaSO_4.H_2O$	CSH_2	3.5

Source: Mindess, Young and Darwin (2003)

When Portland cement is mixed with water its chemical compound constituents undergo a series of chemical reactions that cause it to harden or set. These chemical reactions all involve the addition of water to the basic chemical compounds are listed in Table 2.1. This chemical reaction with water is called hydration. Each one of these reactions occurs at a different time and rate. Together, the results of these reactions determine how Portland cement hardens and gains strength.

C_3S hydrates and hardens rapidly and is largely responsible for initial set and early strength. Portland cements with higher percentages of C_3S will exhibit higher early strength. C_2S hydrates and hardens slowly and is largely responsible for strength increases beyond one week. C_3A hydrates and hardens the quickest. Liberates a large amount of heat almost immediately and contributes somewhat to early strength C_4AF hydrates rapidly but contributes very little to strength. Its use allows lower kiln temperatures in Portland cement manufacturing. Most Portland cement color effects are due to C_4AF.

Portland cement is made to meet the specification requirements of ASTM C 150-05 (2005) for types I, II, III, IV, and V. Ordinary Portland Cement Type I is admirably suitable for use in general concrete when construction. Table 2.2 shows eight basic types of Portland cement concrete.

Table 2.2: Types of Portland cement

Type	Name	Purpose
I	Normal	General-purpose cement suitable for most purposes.
IA	Normal-Air Entraining	An air-entraining modification of Type I.
II	Moderate Sulfate Resistance	Used as a precaution against moderate sulfate attack. It will usually generate less heat at a slower rate than Type I cement.
IIA	Moderate Sulfate Resistance- Air Entraining	An air-entraining modification of Type II.
III	High Early Strength	Used when high early strength is needed. It is has more C_3S than Type I cement and has been ground finer to provide a higher surface-to-volume ratio, both of which speed hydration. Strength gain is double that of Type I cement in the first 24 hours.
IIIA	High Early Strength- Air Entraining	An air-entraining modification of Type III.
IV	Low Heat of Hydration	Used when hydration heat must be minimized in large volume applications such as gravity dams. Contains about half the C_3S and C_3A and double the C_2S of Type I cement.

Source: ASTM C 150-05 (2005)

2.3.4 Water

In the production of concrete, water plays very important role. The water used should not contain any substance that might affect the hydration of cement and affect the durability of concrete. Generally, supplied tap water will be used throughout the study in mixing, curing and other purposes. Water is the key ingredient, which when mixed with cement, forms a paste that binds the aggregate together. The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products. Details of the hydration process are explored in the next section. The water needs to be pure in order to prevent side reactions from occurring which may weaken the concrete or otherwise interfere with the hydration process. The role of water is important because the water to cement ratio is the most critical factor in the production of perfect concrete. Too much water reduces concrete strength, while too little will make the concrete unworkable. Concrete needs to be workable so that it may be consolidated and shaped into different forms such as walls and domes. Because concrete must be both strong and workable, a careful balance of the cement to water ratio is required when making concrete

2.4 MODIFIED CONCRETE

Modified is defined as changing or altering in form or character in order to make it stronger and better than its original form. Frequently, concrete may be used for some special purpose for which special properties are more important than those commonly considered. Sometimes, it may be of great importance to enhance one of the ordinary properties. These special applications often become apparent as new developments using new materials or as improvements using the basic materials.

In material construction, people are trying to modify concretes in order to produce better concrete that are highly resistant, more durable and better quality in construction, but also economical construction when appropriate. Most recent development have relied on the modifications of concrete by using various types of pozzolans, especially waste pozzolans such as POFA, rice husk ash, silica fumes as partial cement replacement in concrete. By reusing the waste products from industries, the source of the pollutions can be reduced, helps to reduce the cost of waste management and make our environment more sustainable (Ali, 2000).

2.5 AGRICULTURAL WASTE AS PARTIAL SAND REPLACEMENT IN CONCRETE

Many researchers nowadays have done research in order to replace sand inside concrete by using agricultural waste. The worldwide consumption of sand as fine aggregate in concrete production is very high, and several developing countries have encountered some strain in the supply of natural sand in order to meet the increasing needs of infrastructural development in recent years. This situation is responsible for increase in the price of sand, and the cost of concrete (Raman, 2007). Due to continuous increasing of the cost of making up concrete, the use of supplementary materials such as biogenic wastes for example palm oil fuel ash, rice husk ash, ash from timber have become significant in concrete industry. Table 2.3 illustrates studies conducted by researches related to utilization of waste as partial sand replacement in concrete.

Table 2.3: Studies conducted by researches related to utilization of waste as partial sand replacement in concrete

Source	Research Area
Rafat (2002)	Class F fly ash as partial replacement of fine aggregate in concrete
Mannesh (2010)	Crushed granite fine as replacement of river sand in concrete
Ismail and Enas (2009)	Waste iron as replacement to sand in concrete
Eun Ik (2009)	Dry oyster shell as partial replacement of sand in concrete
Ismail and Enas (2008)	Waste glass as partial replacement of fine aggregate in concrete

Different types of sand replacement give different results of concrete mechanical properties. For example, by using fine aggregate replacement with Class F fly ash (Bakoshi , 1998) we need to used bottom ash in amounts of 10 – 40% as replacement for fine aggregate. Test results indicate that the compressive strength and tensile strength of bottom ash concrete generally increases with the increase in replacement ratio of fine aggregate and curing age. The freezing–thawing resistance of concrete using bottom ash is lower than that of ordinary concrete and abrasion resistance of bottom ash concrete is higher than that of ordinary concrete. According to Mannesh (2010), peak compressive strength and indirect tensile strength values were obtained when crushed granite fine was replaced with 20% river sand as fine aggregate in the production of concrete. Other than that, the reuse of waste iron as a partial replacement of sand in concrete periods tend to increase above the reference concrete mixes with an increasing ratio of waste-iron aggregate in terms of the flexural strengths of waste-iron concrete mixes at all curing. The highest flexural strength was that of the concrete specimens containing 20% waste-iron aggregate at 28 days of curing, which is 27.86% higher than the reference mix at the same curing period.

The compressive strengths of the concrete mixes made of 20% waste-iron aggregate increase above the reference concrete. The results show that the concrete mixes made with waste iron had higher compressive strengths and flexural strengths than the plain concrete mixes (Ismail and Enas, 2009). Another researcher, Eun Ik (2009) highlighted that utilizing dry oyster shell substituted for fine aggregate did not show negative influences on freezing and thawing, carbonation, and chemical attack resistance, and permeability resistance was improved. Basically, incorporation of suitable waste material as partial fine aggregate replacement at a suitable proportion can improve the concrete performance.

2.6 POFA FROM MALAYSIA PALM OIL INDUSTRY

POFA is an agro-waste generated in palm oil industry. It is obtained from the combustion of palm fruit residues of oil palm tree. The oil palm was first introduced in Malaysia in 1870 as an ornamental plant (Lim, 2003). It is now a leading agricultural cash crop in Malaysia. Currently, there are more than three million hectares of palm oil plantation in this country (Safiudin, Salam and Jumaat, 2010). The palm oil is extracted by pressing the palm fruit bunches of oil palm tree. Since the production of palm oil is increasing continuously in Malaysia, more palm oil fuel ash will be produced and the failure to find any solution for utilizing this ash shall create a severe environmental problem due to uncontrolled disposal.

Palm oil fuel ash (POFA) has the potential to become concrete substituent as it contains siliceous compositions with high specific surface area and reacted as pozzolans to produce a stronger and denser concrete. The major chemical composition of POFA is SiO_2, about more than 50%. Based on the chemical analysis, all of those POFA, in general, satisfied the requirement of pozzolana, and may be grouped in class C pozzolan as specified in ASTM C618-08 (2008). The grinding process increased both the fineness and the specific gravity of POFA. This was due to the crushing of porous particles, which usually have low specific gravity, into smaller particles with lower porosity (Cheerarot, 2004). To resolve the environmental problem caused by POFA, this waste has been processed and used to produce concrete such as normal concrete (Kiattikomol and Siripanichgorn, 2007) , high strength concrete (Tangchirapat and Jaturapitakkul, 2009) and high performance concrete (Tangchirapat, Jaturapitakkul and Saeting, 2007).

2.6.1 POFA as Partial Cement Replacement in Concrete

There are many experimental works conducted by introducing palm oil fuel ash (POFA) as a replacement of the cement with different percentages to improve the properties of concrete. From the previous research, the replacement percentage of cement ranges from 10% to 40% (Sata, Jaturapitakkul and Kiattikomol, 2004). POFA substitution had been used in various kind of concrete research such as POFA cement-based concrete (Hao, 2010), aerated concrete (Abdullah, 2006) and high strength concrete (Kraiwood, 2004). The method used for POFA concrete curing is water curing. Suitable addition of POFA in concrete mix would be able to produce strong and durable concrete (Awal, 1997).

According to research done by Sata, Jaturapitakkul and Kiattikomol, 2004, the replacement of cement with 20% by ground POFA produce higher compressive strength after 7 days than that of 10%, 30% and normal concrete. This is due to the high content of SiO_2 and the high fineness of ground POFA, which helps to react with $Ca(OH)_2$ to produce an additional calcium silicate hydrate, which improves the compressive strength of concrete. The use of 30% of ground POFA as cement replacement produces the lowest compressive strength. The use of POFA as cement replacement shows low early strength but higher ultimate strength that is after the age of 7 days. The density and strength development of POFA concrete is increasing by time.

The earlier researchers claims that they have successfully integrated POFA as partial cement replacement in normal concrete that enhanced strength and durability of concrete (Awal and Hussin, 1997). Integration of POFA as partial cement replacement, especially very fine POFA increase the durability and resistance of high strength POFA concrete in chemical environment towards chloride penetration, acid and sulphate attack. (Husin, Ismail, Muthusamy and Budiea, 2009). The utilization of POFA having higher fineness in concrete speeds up the pozzolanic reaction resulting towards formation of more extra C-S-H gel making the concrete denser and enabling it to exhibit better resistance to chloride, acid and sulphate attack.

2.6.2 POFA as Partial Sand Replacement in Concrete

So far, ground palm oil fuel ash (POFA) has been used as partial sand replacement for production of aerated concrete in the study conducted by Mat Yahaya (2003). However, no study has been conducted on utilization of unground POFA as partial sand replacement in concrete making.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

At the beginning of this chapter, the preparation of cement, sand, coarse aggregate and water is presented. Then, followed by detail elaboration on the steps taken to process palm oil fuel ash (POFA) until it is ready to be used for concrete production. This chapter also elaborates on the step taken to prepare concrete mixes which includes process of mixing, casting and curing until it is ready to be tested. The steps followed to conduct testing in order to study the concrete properties are also explained in this chapter.

3.2 RAW MATERIALS

In this study, the raw materials used for production of concrete specimen consist of ordinary Portland Cement (OPC), sand, coarse aggregate, water and palm oil fuel ash (POFA).

3.2.1 Cement

Ordinary Portland Cement (OPC) produced by YTL Sdn Bhd from a single source is used throughout this research in order to make sure that the cement used has the same properties and chemical compositions. This type of cement is identified as type I according to ASTM C 150-05 (2005) which is suitable for general concrete work. The cement bags are stored away from damp floors and stacked close together in a well-aired, clean and dry place. Figure 3.1 shows the cement used.

Figure 3.1: Cement

3.2.2 Sand

The type of sand used throughout this study is river sand. It is air-dried before kept in the container protecting it from getting wet due to rain or moisture from the surroundings. Figure 3.2 shows the fine aggregate used in this experiment.

Figure 3.2: Sand

3.2.3 Coarse Aggregate

In this study crushed aggregates with the sizes ranging from 10-14 mm is used. The coarse aggregate used has been subjected to air drying method in order to obtain saturated surface dry condition. Figure 3.3 shows the coarse aggregate used.

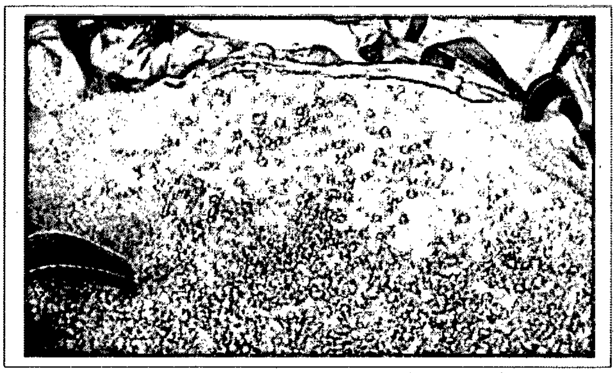

Figure 3.3: Coarse aggregate

3.2.4 Palm Oil Fuel Ash (POFA)

Collected POFA from palm oil located in Felda Lepar Hilir, Gambang was subjected to oven dry at 105 ± 5°C to remove moisture in it. It was found that the moisture absorption of POFA is 0.056 %. The POFA used in this study grayish in color as illustrated in Figure 3.4. The oven-dried POFA are sieve into three different types of fineness that are POFA passing 300 μm, POFA passing 600 μm and POFA passing 1.18 mm.

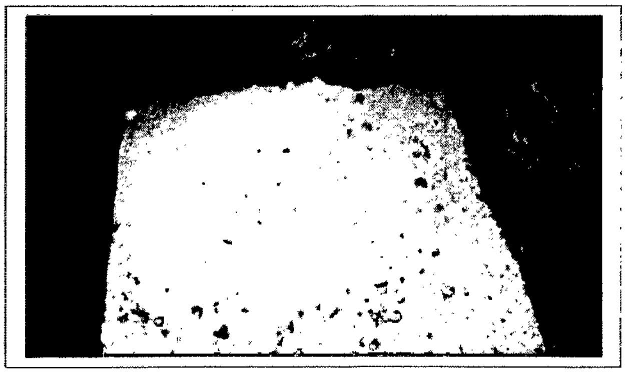

Figure 3.4: Palm oil fuel ash (POFA)

3.2.5 Water

In concrete production, enough water to be added is important to make the mix workable. Supplied tap water has been used in mixing, curing and on other purpose throughout the experiment.

3.3 CONCRETE MIX DESIGN

Method of design used in designing the mix is according to Department of Environment (DOE) United. The concrete are design as Grade 30. The fine aggregates are placed by POFA of 10 % by weight of fine aggregates. Concrete without any POFA replacement act as control specimen. The mix design used in this research is shown in Table 3.1.

Table 3.1: Quantities of the constituents per cubic metre

Constituents	Weight (kg/m^3)
Cement	426
Water	230
Sand	774
Coarse aggregate	860
Palm Oil Fuel Ash (POFA)	86

3.4 SPECIMEN PREPARATION

The materials were weighed and placed in a mixer according to order. In the process of making concrete, aggregate is mixed with water and sand prior to the addition of cement and POFA. The concrete is mixed for 5 minutes and cast into (100x100x100) mm steel cube moulds. Cubes are filled in 3 equal layers. Then it is vibrated using the vibrating table. The moulds must be rigidly clamped on the platform to enable the system to vibrate in unison. After the vibration process, it should be properly levelled and finished using hand trowel. Then, cubes is demoulded after 24 hours and then subjected to water curing until it is time to be tested.

3.5 WORKABILITY TEST

Three tests namely slump test, compacting factor test and Vebe test have been conducted in this study to measure workability of the mixes. The test is in accordance to the existing standard.

3.5.1 Slump Test

Slump test is carried out to measure the consistency of plastic concrete. It is suitable for detecting changes in workability. The slump test for all type of mixes is conducted in accordance to MS 26 Part 1: Section 2 (2009). Below are the workability categories for slump test and procedures for slump test:

Table 3.2: Workability categories for slump test

Workability Category	Slump (mm)
Extremely Low	0
Very Low	0-10
Low	10-30
Medium	30-60
High	60-80

Source: MS 26 Part 1: Section 2 (2009)

At the beginning of test, the inside mould and its base was moistened and cleaned thoroughly in order to reduce the influence on slump by surface friction. The mould for the slump test is a frustum of a 300 mm high cone. It was placed on smooth horizontal, rigid and non-absorbent surface with the smaller opening at the top and filled with concrete in three layers. When filling in the concrete, the mould must be firmly held against is base during the entire operation. The mould was filled in 4 layers each approximately one quarter of the height of mould. Each layer was tamped 25 times with a standard 16 mm diameter steel rod, rounded at the end. The stroke should be distributed in a uniform manner over the cross section of mould.

Then, the top surface is struck off by means of a sawing and rolling motion of the tamping rod. Immediately after lifting, the cone was slowly lifted in vertical direction within 5 to 10 seconds and the unsupported concrete will slump. The slump must be measured immediately by determining the difference between height of mould and that of highest point of slumped concrete specimen. The decrease was measured to the highest point according to MS 26 Part 1: Section 2 (2009). The above operation has been carried out in a place free from shock or vibration. Figure 3.5 shows the slump test apparatus.

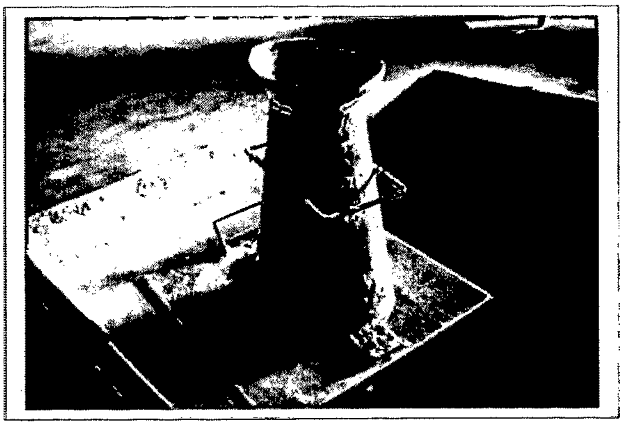

Figure 3.5: Slump test apparatus

3.5.2 Compacting Factor Test

The compaction factor is defined as the ratio of the mass of the concrete compacted in the compaction factor apparatus to the mass of the fully compacted concrete. The degree of compaction, called the compacting factor, is measured by the density ratio. The test has been carried out following the procedures outline in MS 26 Part1: Section 8 (2009).

Table 3.3: Workability categories for compacting factor test

Workability Category	Compacting Factor
Extremely Low	0.65-0.70
Very Low	0.70-0.75
Low	0.75-0.85
Medium	0.85-0.95
High	0.95-1.0

Source: MS 26 Part1: Section 8 (2009)

The apparatus consists essentially of two hoppers, each in the shape of a frustum of a cone, and one cylinder, the three being above one another. The hoppers have hinged door at the bottom as shown in Figure 3.6. Before carrying out this test, empty cylinder is weighted and the mass is recorded to the nearest 10 gram. Other than that, the internal surfaces of the hoppers and cylinder must be make sure that it is smooth, clean and damp but free from the superfluous moisture. The upper hopper is filled with concrete prepared according to mix calculation. This concrete must be places gently so that no work at this stage was done on the concrete to produce compaction.

The bottom door of the hopper is the released and the concrete falls into the lower hopper. The second hopper is smaller than the first one. Therefore the hopper was filled to overflowing. Once all of the concrete has fallen from the top hopper, the door on the lower hopper is opened to allow the concrete to fall to the bottom cylinder. A tamping rod can be used to force especially cohesive concretes through the hoppers. The excess concrete is carefully struck off the top of the cylinder and the mass of the concrete in the cylinder is recorded. This mass is compared to the mass of fully compacted concrete in the same cylinder achieved with hand rodding or vibration.

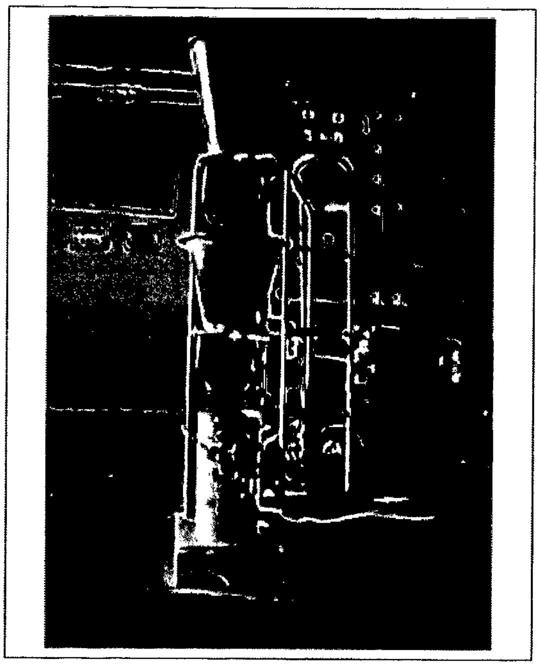

Figure 3.6: Compacting factor apparatus

3.5.3 Vebe Test

This test which conducted in accordance to MS 26 Part 1: Section 3 (2009) is used to determine workability of the mixes. The workability categories for Vebe Test are tabulated in Table 3.4. The concrete prepared according to mix ratio calculated was placed inside the slump cone and then the cone is removed. Then, a disc-shaped rider was placed on top of the concrete cone. Watch used to count the time which starting from the moment where the vibration table is switched on until it was switched off. The vibrating table was then switched on and the concrete was vibrated until the cone change to the shape of the cylinder. Vibrating time which taken from the moment the vibrating table is switched in until it is switched off is recorded. Figure 3.7 shows the Vebe Test machine.

Table 3.4: Workability categories for vebe test

Workability Category	Vebe Time (s)
Extremely Low	Over 20
Very Low	12-20
Low	6-12
Medium	3-6
High	0-3

Source: MS 26 Part 1: Section 3: 2009

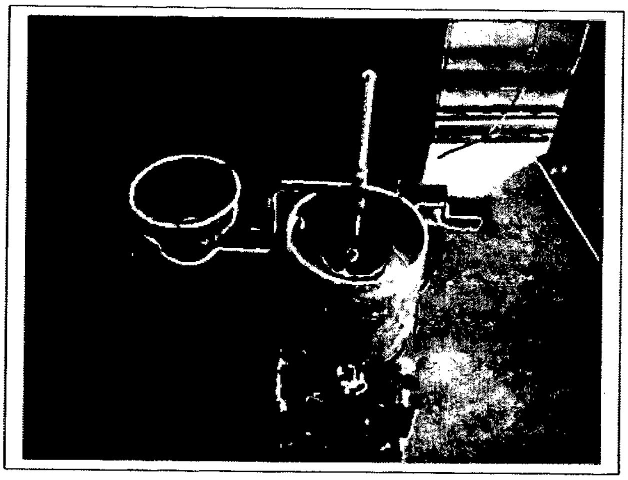

Figure 3.7: Vebe test machine

3.5.4 Compressive Strength Test

A compressive strength test determines behavior of materials under crushing loads. An increasing compressive load was applied to the specimen until failure occurred to obtain the maximum compressive load. The compressive strength has been following the procedures conducted specified MS 26: Part 2: Section 3 (1991). The cubes are tested at the ages of 28 days. Firstly, the hardened concrete is measured by its weight and diameter of each specimen. It needs to be measured in several locations, both horizontally and vertically. The concrete is placed between the compression plates with the appropriate cushioning material. The load is then slowly applied without a shock. The highest load reached is observed and record. After the load begins to decrease, the load is removed. The same process for other specimens will be repeated. Ultimate strength for each specimen is calculated. Figure 3.8 shows the compression test machine.

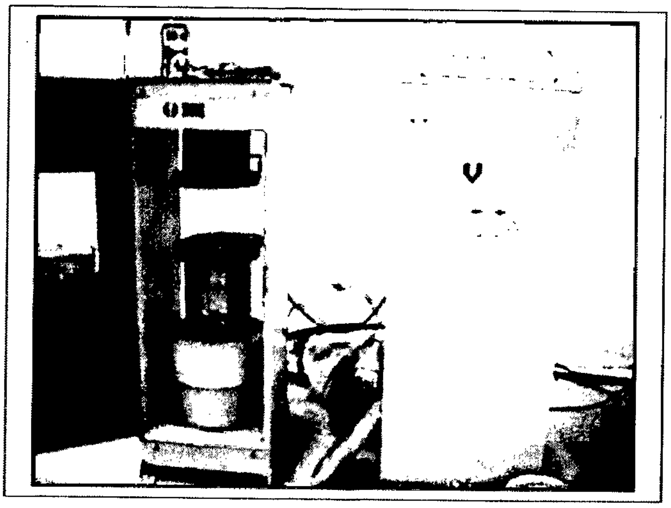

Figure 3.8: Compressive strength test machine

3.5.5. Water Absorption

Water absorption test was is usually carry out by measuring a specimen to a constant mass, immersing it in water and measuring the increase in mass as a percentage of dry mass. Water absorption is done in accordance to the test requirement of BS 1881: Part 122: 1983. Concrete cubes are cured before subjected to water absorption test at the age of 24 days. Before carrying out the testing, the specimens were oven dried to constant mass at 105 ± 5 °C for 72 ± 2 hours. The concrete specimens are weighing before immersion and after immersion for 30 minutes.

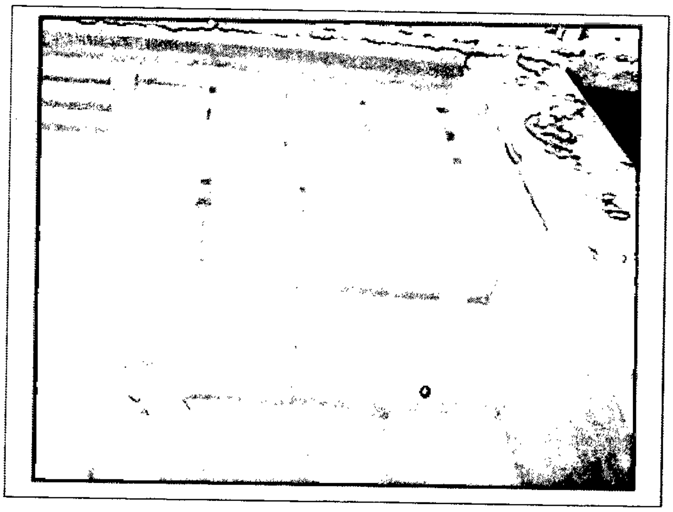

Figure 3.9: Concrete cubes are subjected to water curing for 24 days

CHAPTER 4

ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter presents the discussion on the results of workability, compressive strength, density and water absorption of concrete containing various POFA fineness. Method and test was carried out as described in Chapter 3 of this thesis. The influence of POFA fineness is also discussed in this chapter. All this information retrieved will become a very useful for future study and future development of building materials.

4.2 Effect of Different POFA Fineness as Partial Fine Aggregate Replacement towards Workability

4.2.1 Slump Test

Figure 4.1 shows slump result of fresh concrete containing different POFA fineness. It has been observed that the slump pattern of the specimen is influenced by different sizes of POFA particles. Concrete POFA passing 1.18 mm sieve has the lowest workability compared to other mixes. This clearly shows that the use of larger POFA particle size in concrete will lead to stiffer slump compared to other concrete mixing made using by finer POFA particle. On the contrary, concrete POFA passing 300 μm shows the highest workability with results of 130 mm.

The use of POFA passing 1.18 mm in concrete production will require a higher water to cement ratio as it absorbs high water during mixing process when compared with values obtained with the use of other different POFA particles. This is due to porous POFA particles confined a portion of mixing water due to greater surface areas,and thus reduced the quantity of free water in concrete mixture. Therefore, the water needed for the lubrication action of binder paste became lower in POFA concrete. Consequently, the concrete slump flow was reduced. Variation of slump pattern is illustrated in Figure 4.2, 4.3, 4.4 and 4.5 respectively.

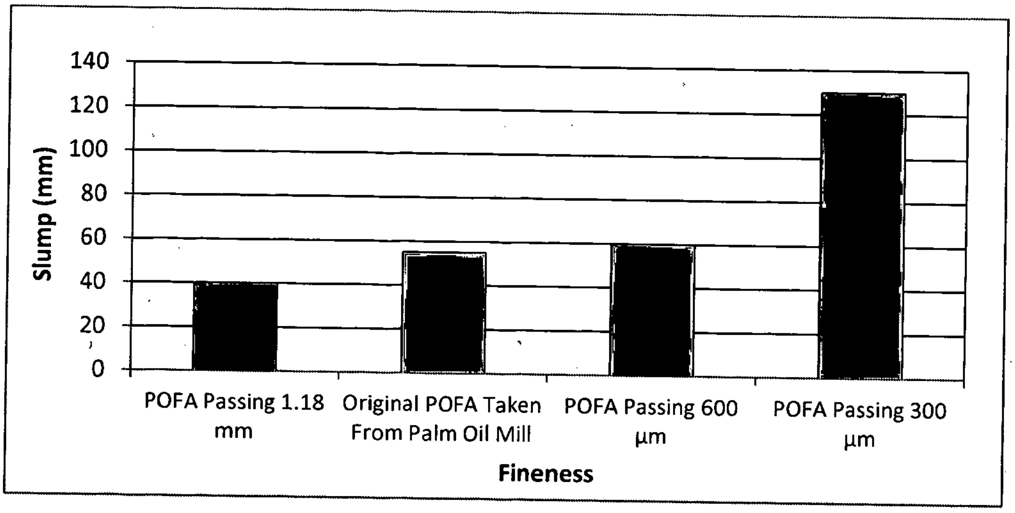

Figure 4.1 Effect of POFA fineness on slump result

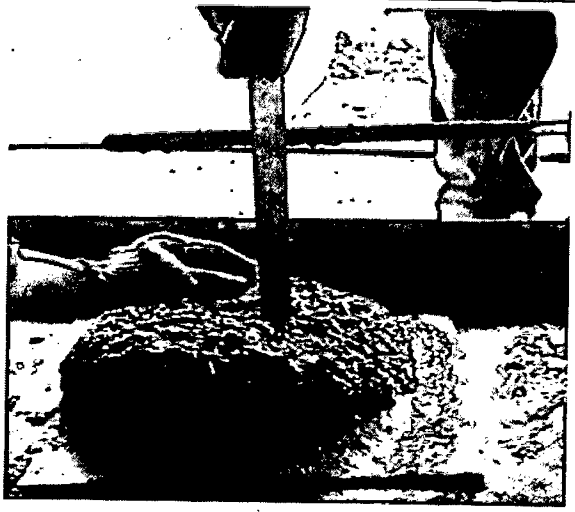

Figure 4.2 Slump of concrete POFA passing 300 μm

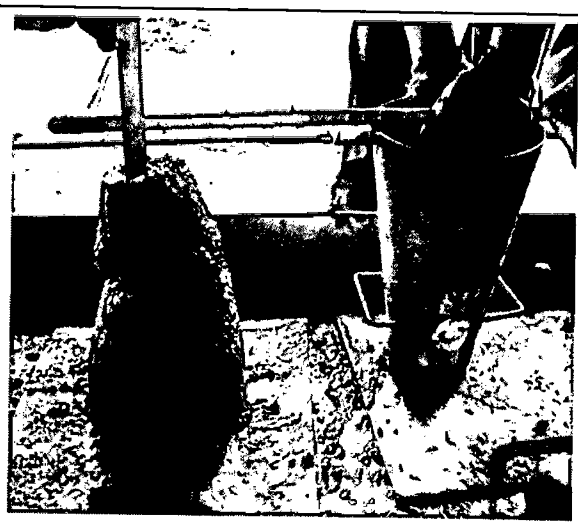

Figure 4.3 Slump of concrete POFA passing 600 μm

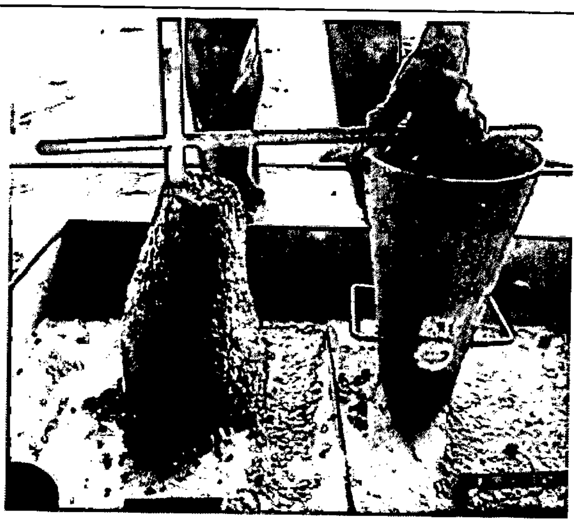

Figure 4.6 Slump of concrete POFA originally taken from palm oil mill

Figure 4.5 Slump of concrete POFA passing 1.18 mm

4.2.2 Compaction Factor Test

As presented in Figure 4.6, it can be seen that the compacting factor value is also influenced by different sizes of POFA particles. The figure shows that concrete POFA passing 1.18 mm sieve has the lowest compacting factor that is 0.94 and it can be indicate as medium workability. For the other mixes, the results are range in between 0.96 to 0.99 which is high workability categories. The most workable mix is shown by POFA passing 300 μm that is 0.99. Use of smaller particle size of POFA in concrete results in higher compaction factor ratio compared to concrete mix consisting larger POFA particle. On overall, the trend presented in this result is similar to slump test result presented in the previous sub section.

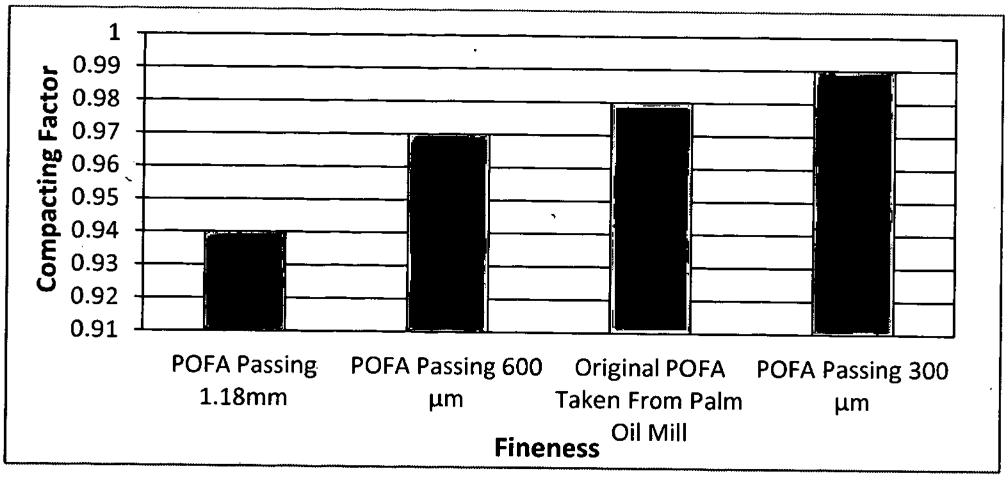

Figure 4.6 Effect of POFA fineness on compacting factor

4.2.3 Vebe Test

Figure 4.7 shows that vebe time become longer as the POFA particle size added in the mix become larger. The shortest vebe time which is 1 second exhibited by concrete mix containing POFA passing 300 µm. The longest vebe time can be observed for concrete consisting POFA passing 1.18 mm. These vebe time become bigger when POFA having larger is used. This is because the use of POFA passing 1.18 mm in concrete production will require a higher water to cement ratio as it absorbs high water during mixing process thus results in stiffen concrete mix.

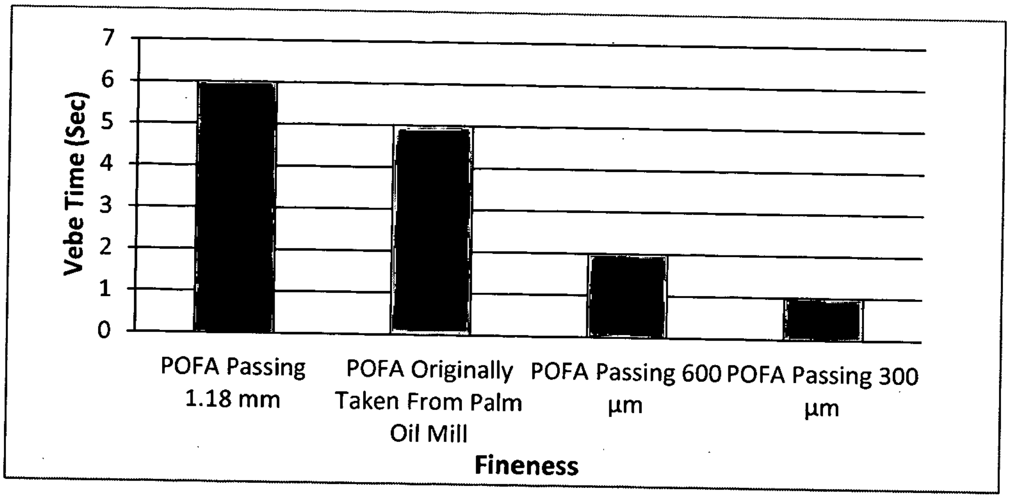

Figure 4.7 Effect of POFA fineness on vebe time

4.3 Effect of Different POFA Fineness as Partial Replacement towards Compressive Strength of Concrete

The strength of concrete assumes a greater significance because the strength is related to the structure of hardened cement paste and gives overall picture of the quality of concrete (Gambhir, 2004). The most common measure of concrete strength is the compressive strength. The compression test shows the best possible strength of concrete that can be reached in perfect conditions.

In this study, concrete specimens having three different fineness of POFA were made and tested at 7, 14 and 28 days. The entire POFA concrete specimens prepared consist of 10% POFA as partial sand replacement material. Four types of mixes were prepared using POFA possessing different fineness namely original POFA taken from palm oil mill, POFA passing 1.18 mm sieve, POFA passing 600 μm sieves and POFA passing 300 μm sieves. For each mixes, there are three samples for each test and the average results are taken.

Figure 4.8 shows the compressive strength of concrete containing palm oil fuel ash (POFA) of different fineness at 7, 14 and 28 days. All the specimens exhibit continuous strength development as the curing day become longer. It can be seen that the use of POFA with different fineness causes variation in the compressive strength performance of concrete. The compressive strength for POFA concrete passing 1.18 mm sieves, passing 600 μm, passing 300 μm and POFA originally taken from palm oil mill at 28-days of curing are 13.54 MPa, 14.27 MPa, 15.52 MPa and 15.57 MPa respectively.

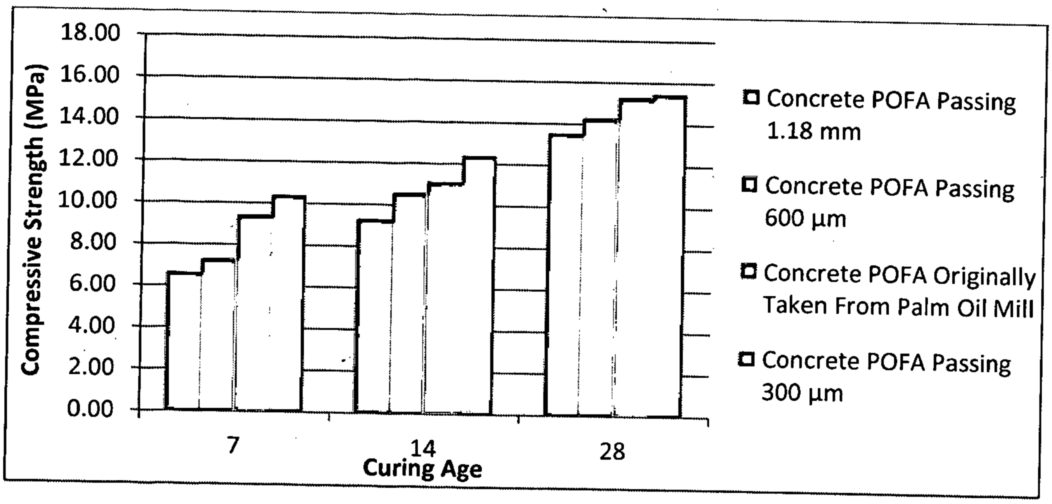

Figure 4.8: Effect of POFA Fineness on compressive strength of concrete at the age of 7, 14 and 28 days.

It is found that concrete produced using POFA passing 300 μm exhibit highest value of compressive strength that is 15.57 MPa at the age of 28 days compared to other

POFA specimens. The better performance of concrete POFA passing 300 μm is probably due to the small POFA particles that fill the voids between the gravel and sand particles while cement binds the components together. Thus, denser and stronger hardened concrete is produced as compared to other POFA concrete mixes. In other words, the more solidly all voids will be filled, and the denser and stronger will be the concrete.

Concrete containing POFA passing 1.18 mm exhibit the lowest strength value that is 13.5 MPa at the age of 28 days compared to other specimens. The poor performance of this concrete is probably because of the concrete difficulty to be compacted during casting process. During the mixing work, the particle of POFA passing 1.18 mm is larger than other particles and absorbs high amount of water which used for mixing work. Since the compaction is not perfectly done, samples are not well compacted resulting highly porous cube which has very low capacity to carry load. The difference in the physical appearance made of POFA passing 300 μm and 1.18 mm can be seen in Figure 4.9 and 4.10 respectively. Evidently, cube produced using concrete mix consisting 1.18 mm appear to be more porous and brittle as compared to the cube made using mix containing POFA 300 μm. Conclusively, it can be deduced that, strength of concrete increases as the POFA used become finer.

Figure 4.9: Compressive strength failure of POFA passing 300 μm

Figure 4.10: Compressive strength failure of POFA passing 1.18 mm

4.4 Effect of Different POFA Fineness as Partial Replacement towards Concrete Density

Figure 4.11 shows the density of concrete containing palm oil fuel ash (POFA) of different fineness. The density of concrete drops when POFA is used as partial sand replacement and it continuous to decrease as the size of POFA used becomes larger. The density for POFA concrete passing 300 μm, passing 600 μm, POFA originally taken from site and 1.18 mm sieves are 2350 kg/m^3, 2320 kg/m^3, 2300 kg/m^3 and 2250 kg/m^3.

The relationship between the strength and density of the material presented in Figure 4.11 proves that strength of concrete continues to decrease together with the density as the size of POFA used become larger. The low density of concrete is probably due to high presence of voids inside it. The presence of voids in concrete reduces the density and greatly reduces the strength.

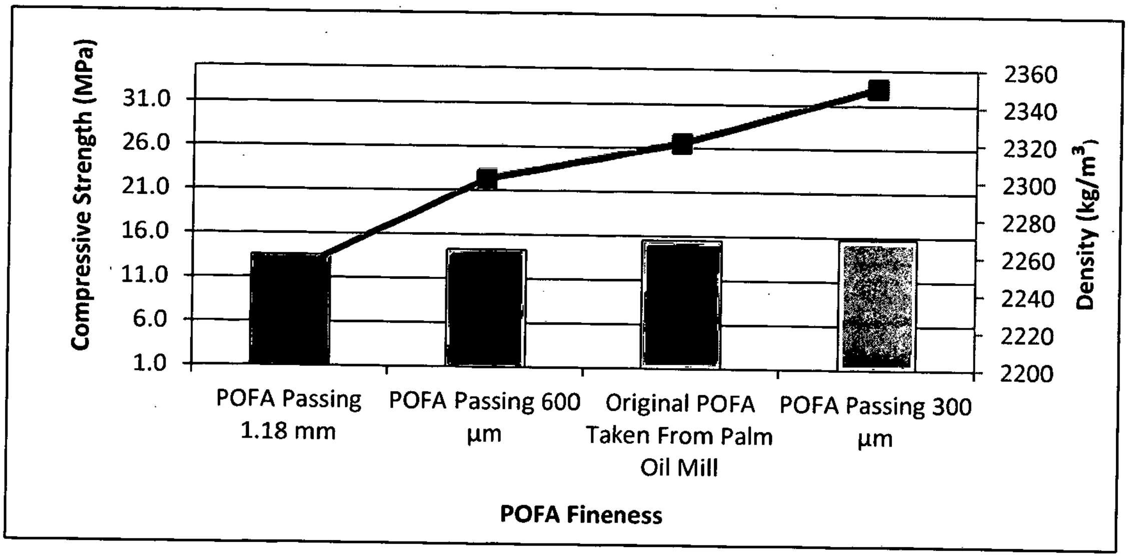

Figure 4.11: Effect of POFA fineness on compressive strength with density

4.5 Effect of Different POFA Fineness towards Density and Water Absorption

Figure 4.12 shows that the concrete specimen made of larger POFA particle size absorbs higher amount of water compared to concrete made using finer POFA particle. It can be observed that reduction in density of concrete caused by larger POFA particle size tends to increase the percentage of moisture absorbed.

Concrete containing POFA passing 1.18 mm sieve has the highest percentage of water absorption that is 3.74%. Then, followed by concrete containing POFA taken directly from the palm oil mill, concrete containing POFA passing 600 µm and concrete containing POFA passing 300 µm with the percentage of water absorbed that is 3.71%, 3.43% and 3.20% respectively. This result is proportional to the increasing density of concrete that are 2250 kg/m³, 2300 kg/m³, 2350 kg/m³ and 2400 kg/m³.

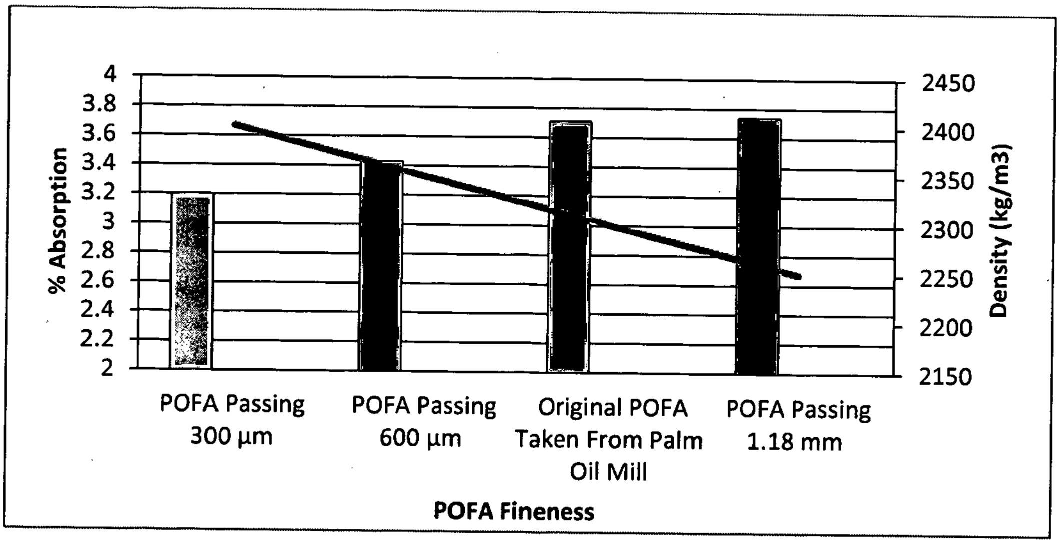

Figure 4.12: Effect of POFA fineness on water absorption

Concrete consisting POFA passing 300 µm which is the smallest size than other POFA size used is denser than other specimens exhibit lowest water absorption. POFA passing 300 µm when added in the mix tends to fill the voids in the concrete making it denser as compared to the concrete consisting POFA with larger size. This will cause the concrete to become stronger and less permeable causing less water is absorbed.

The use of larger particle size of POFA causes the concrete workability became low leading to difficulties during compacting process. As a result, concrete having larger amount of voids were formed. This lead to higher percentage of water absorbed when the specimens consisting larger POFA size is immersed into the water. Conclusively, integration of POFA with higher fineness in the mix reduces the percentage of water absorbed by the concrete.

CHAPTER 5

CONCLUSION AND RECOMMENDATION FOR FUTURE STUDY

5.1 INTRODUCTION

This final chapter forms the conclusion of this research, drawing out the key point of the objectives, analysis and important research findings from the previous chapter. This chapter also highlighted several recommendations to enhance the POFA concrete quality for future study.

5.2 BRIEF CONCLUSION

Objective from the study of properties of concrete containing POFA with different fineness as partial sand replacement are briefly concluded below.

5.2.1 Effect of POFA Fineness Towards Workability of Concrete Containing POFA as Partial Sand Replacement

It was observed that the workability of concrete reduces when higher fineness of POFA is added. Mix consisting finer POFA particle as partial sand replacement exhibit higher workability which can be observed in the higher value of slump, lower degree of compaction and shorter vebe time.

5.2.2 Effect of POFA Fineness Towards Density and Compressive Strength of Concrete Containing POFA as Partial Sand Replacement

Study revealed that utilization of finer POFA results in concrete with higher compressive strength. This is because of the smaller particle size fills the voids between the gravel and sand particles creating a denser and stronger concrete. However, POFA concrete exhibit slightly lower value of strength compared to plain OPC concrete.

5.2.3 Effect of POFA Fineness Towards Water Absorption of Concrete Containing POFA as Partial Sand Replacement

Moisture absorption of concrete becomes lower when using higher fineness of POFA. Porous concrete produced by using bigger particles of POFA as bigger size of POFA absorbs higher moisture content.

5.3 RECOMMENDATIONS

Among the recommendation for this study is as follows.

a. POFA need to be ground until it possess very fine and powdery airborne textured. It is revealed that ground POFA is an excellent pozzolanic material and can be used as an alternative cement replacement in concrete. It is recommended that the optimum replacement levels of OPC by POFA are 30% and 20% mixture for a good strength in compressive test.

b. The action of plasticizer is mainly to fluidify the mix and improve the workability of concrete. Thus, the use of plasticizer is the most important admixtures in enhancing POFA concrete performance.

c. Curing period for POFA concrete should be extend to study the long-term investigation and effect of pozzolanic reaction on compressive strength as this study was conducted for only short period.

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