THE EFFECT OF PALM OIL FUEL ASH (POFA) AS PARTIAL CEMENT REPLACEMENT MATERIAL ON CONCRETE TOWARD HEAT GENERATION

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ABSTRACT

Pozzolanic materials are natural or artificial materials produced from combustion of the waste. In Malaysia, the utilization of the pozzolanic materials has been widely used in concrete construction which used as a partial replacement material in concrete. The uses of pozzolanic become increasingly widespread in recent times because of technological, economic and ecological advantages of the material contained on pozzolanic. In this study, Palm Oil Fuel Ash (POFA) was utilized as pozzolanic material in concrete. POFA is by-product obtained by burning of fibers, shells and empty fruit bunches as fuel in palm oil mill boilers. The original sizes of POFA were passing 63μm. Portland cement Type 1 was partial replaced by 10%, 20% and 30% of POFA by weight of cement used. The behaviors of POFA performance in reducing temperature during hydration, drying shrinkage and compressive strength due to the different percentage of partial cement replacement in concrete. The samples were used to undergo heat test where sample 1 is mixer control which contains 100% PC and another 3 samples containing 10%, 20% and 30% of POFA as a partial replacement from amount of the cement used. From the experiments it was found that samples containing 20 % POFA as partial replacement of cement decreasing temparature compared with 100% PC. Besides that, POFA as a partial replacement of cement not only reduces the amount of temperature rise but also delay the time at which the peak temperature occurs The drying shrinkage test showed that the concrete containing 10% of POFA was much low loss moisture compare with other samples. However, the compressive strength of POFA concrete was much lower that the PC concrete. The results obtained and the observations made clear that the partial replacement of cement by POFA beneficial, especially in the construction of concrete.

ABSTRAK

Bahan pozzolanic adalah bahan semula jadi atau buatan dihasilkan daripada pembakaran sisa buangan. Di Malaysia, penggunaan bahan pozzolanic telah digunakan secara meluas dalam pembinaan konkrit yang digunakan sebagai bahan gantian separa di dalam konkrit. Kegunaan pozzolanic menjadi semakin berleluasa sejak kebelakangan ini kerana kelebihan teknologi, ekonomi dan ekologi bahan yang terkandung dalam pozzolanic. Dalam kajian ini, Palm Oil Fuel Ash (POFA) telah digunakan sebagai bahan pozzolanic dalam konkrit. POFA adalah produk yang diperolehi dengan membakar gentian, cengkerang dan tandan buah kosong sebagai bahan api dalam dandang kilang minyak sawit. Saiz asal POFA telah melepasi 63μm. Portland simen Jenis 1 telah digantikan separa dengan 10%, 20% dan 30% daripada POFA daripada berat simen yang digunakan. Tingkah laku prestasi POFA dalam mengurangkan suhu semasa penghidratan, pengecutan dan kekuatan mampatan kerana pengunaan peratusan yang berbeza separa gantian simen di dalam konkrit. Sampel yang digunakan untuk menjalani ujian haba di mana sampel 1 adalah bancuhan kawalan yang mengandungi 100% PC dan 3 sampel lagi mengandungi 10%, 20% dan 30% daripada POFA sebagai pengganti separa simen. Dari eksperimen yang dijalankan didapati bahawa sampel yang mengandungi 20% POFA sebagai pengganti separa simen suhu berkurangan berbanding dengan 100% PC. Di samping itu, POFA sebagai pengganti separa simen bukan sahaja mengurangkan jumlah kenaikan suhu tetapi juga melambatkan masa di mana suhu puncak berlaku Ujian pengecutan pengeringan menunjukkan bahawa konkrit yang mengandungi 10% daripada POFA adalah lebih rendah kehilangan lembapan berbanding dengan lain-lain sampel. Walau bagaimanapun, kekuatan mampatan konkrit POFA adalah lebih rendah yang konkrit PC. Keputusan yang diperolehi dan pemerhatian yang dibuat jelas bahawa penggantian separa simen oleh POFA bermanfaat, terutama dalam pembinaan konkrit.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Symbol		Item
%	-	Percentage
mm^2	-	Newton per millimeter square
μm	-	Micrometer
m^3	-	Meter Cubes
g	-	Gram
°C	-	Degree celcius

LIST OF ABBREVATIONS

BS	-	British Standard
UMP	-	University Malaysia Pahang
FKASA		Fakulti Kejuruteraan Awan dan Sumber Alam
ASTM	-	American Society for Testing and Materials
POFA		Palm Oil Fuel Ash
PC		Portland cement
CO_2	-	Carbon dioxide
SiO_2	-	Silicon oxide
Al_2O_3	-	Aluminum oxide
Fe_2O_3	-	Iron oxide
CaO	-	Calcium hydroxide
MgO	-	Magnesium oxide
K_2O	-	Potassium oxide
Na_2O	-	Natrium oxide
SO_3	-	Sulfur trioxide
w/c	-	Water cement
NiO	-	Nickel (II) oxide
Cl	-	Chlorine
P_2O_5	-	Phosphorus pentoxide
$CaCO_3$	-	Calcium carbonate
MPa	-	Mega Pascal

mm	-	Millimeter
min	-	Minute
hr.	-	Hour

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The hydration of cement compound is exothermic compounds where the heat is released into the earth (Abdul Awal et.al,2011). At the ends of the day, when hydrated cement compounds react with water to obtain the state-stable low vitality, and the methodology followed by the arrival of high temperature energy. High temperatures create more number of full hydration of underrated compound at a certain temperature characteristics as the spiciness of hydration. The essentialness heat of hydration of cement engineering is complex. Size pungency is released and the release rate of the high temperature hydration mixture can be used as an individual to record their reactivity

Besides, the high temperatures of hydration depict the setting and solidifying of bond and foresee the conduct of the temperature climb moreover. Cement temperature in light of the fact that hydration is to a great extent controlled by the materials and properties of the mixture and by ecological elements (Abdul Awal et.al, 2010). Truth be told, the high temperature of hydration relies on upon the conduct of synthetic mixes and is very nearly equivalent to the measure of hotness of hydration immaculate mixes separately when each one section by mass was hydrated independently.

Once more, the primary constituents of Portland concrete are limestone illuminate and di-calcium tricalcium. Triclacium in charge of right on time advancement

stage and di-calcium quality to quality improvement following 28 days of hydration. In this manner, the advancement of the measure of hotness is most likely influenced by the amount of concrete in the mixture.

High concrete substance can be valuable to get a higher introductory quality in the solid, however more noteworthy hotness created by the concoction response produces undesirable splitting and shrinkage in cement

1.2 PROBLEM STATEMENT

The proposed study is based on problems that occur in Malaysia. Malaysia is a country that has a warm climate. According to the Malaysian Meteorological Department noted between the highest temperature readings in Malaysia with 38.5℃. This is one of the highest temperatures ever recorded in Malaysia after reading 41℃ temperature ever recorded in Perlis in 1998 (Mosti,2013). This affects the production of cement in the construction industry. it is very important in the construction sector are many ways that were done to reduce heat in the concrete which are used wet gunny (fiber) to prevent the absorption of heat.

Today, Malaysia is a major producer of palm oil. In 2003, Malaysia produced 14 million tons of palm oil from the ground, covering more than 38,000 square kilometers, making it the largest exporter of palm oil in the world (Abd Razak et.al, 2013). Most of the results from banks channeled to market hygiene and culinary use. Conglomerate Sime Darby is the largest oil palm plantation operator, which has 524.626 hectares in the Peninsula, Sabah and Sarawak. Surplus of palm oil will be used as fertilizer and many others.

POFA is classified as a waste material, the production of crude palm oil, a large amount of solid waste is also an output from the palm oil industry (Tangchirapat et al. 2007). To solve the energy problems, solid wastes from palm oil residue are used as fuel

to produce steam for electricity generation. After burning, an ash by-product is produced, which is about 5% by weight of the residue. POFA is minimal and unmanageable, while its quantity increases annually and most of the POFA are disposed of as waste in landfills causing environmental and other problems. There are several types of waste disposal system. The common waste disposal systems used in Malaysia are open burning, ocean dumping, compositing, incineration and land filling. Almost all the wastes in Malaysia are dispose using landfill method and majority of the sites are poorly managed

Therefore, research ~~a~~bout use of a waste material as a replacement to cement is necessary to conduct as recycling POFA into the useful product gives good potential benefit on many levels, both for palm oil industry and a much wider construction industry. This research will focus on the utilization of POFA in the concrete production due concrete as a main building material. The common structure use the mass concrete is slab and foundation. All concretes generate heat as the cementations materials hydrate. Most this heat generation occurs in the first day after placement.

1.3 RESEARCH OBJECTIVE

The objectives of this study are:

i. To identify the temperature of the concrete during hydration by using Palm Oil Fuel Ash (POFA) as a partial cement replacement material.
ii. To determine the drying shrinkage of the concrete by using POFA.
iii. To determine the strength of concrete by using POFA as a partial cement replacement material.

1.4 SCOPE OF STUDY

In the research an attempt to add the POFA as a partial cement replacement stage material in concrete production. The study focus on investigating the temperature of PC concrete with varies percentage of the amount of POFA that are 10%, 20% and 30%

during the hydration time, drying shrinkage and compressive strength of the concrete. Scope of this study includes the following procedures:

i. The size of POFA used as the cement replacement is 63μm that constant size for the entire specimens.
ii. Four sets of the specimen that which PC concrete, 10%, 20% and 30 % POFA concrete.
iii. Specimen used for the heat test 300 x 300 x 300 mm and the mix proportion used from previous study.
iv. After pour concrete into the heat test specimen, the test conducted by using the thermal gauge and data logger.
v. Small amount of the concrete for each specimen used in drying shrinkage test. Duration of drying shrinkage for 7, 28 and 90 days.
vi. The excess concrete, pour into mold size 100 x 100 x 100 mm and curing the concrete for 7, 28 and 90 days to determine the compression strength of the PC concrete and POFA concrete.
vii. The test involved in this study conducted at FKASA lab and central lab, UMP.

1.5 RESEARCH SIGNIFICANCE

This study is very important because waste management is one major issue in Malaysia as this method will help to reduce the amount waste and contribute in reducing the cost of construction. Therefore, it was decided that this is a method to solve the problem from the issues that arise from the problem of waste disposal, including support for environmental problems mainly caused pollution to public health. Besides that, understanding of the effectiveness of the POFA as a partial replacement of cement to the heat generation during hydration, drying shrinkage, compressive strength, levels and chemical content in concrete. At the same time, this study encourages more research to be conducted on the use of POFA in concrete production.

CHAPTER 2

LITERATURE REVIEWS

2.1 INTRODUCTION

Literature review is various studies that discussed the relevant materials which related to this project. Since the POFA is related to the topic, the application and characteristic of POFA waste discussed in this chapter based on previous study. Besides that, characteristic of concrete, cement, aggregate, water and industrial waste also discussed.

2.2 CONCRETE

Concrete is a material that made from cement, aggregate, sand and water at the rate of a particular mixture and allowed to harden to from the particular structure like beam, column or others (Naidu et.al,2014). Sometime a substance or call admixture add into the concrete mix that to make the concrete harden quickly or slow, sulfate resistance, reduce heat and so on. Concrete is the most importance material used in construction because of that the correct technics should be considered to ensure the concrete good quality and the strength can be achieved.

2.2.1 Properties of Concrete

The concrete have its own properties among the concrete hardens and freezes when the presence of water. These properties are important in the construction, especially the construction of the foundation on wet condition. The concrete not rust or rot. It is also not attacked by termites or other insects. Concrete can be molded into any shape according to the mold.

The strength and durability of the concrete is dependent on the amount of water used in concrete mix design. Therefore a few importance things to make sure the viscosity of the concrete mixture must appropriate to enable concrete was mixed well and can be transported, poured and feasible without segregation happen to the original materials (Thomas 2000b) Quality of the concrete also depends on the several factor likes:

i. The quality of the raw materials used in cement, aggregate, sand and water.
ii. The rate of blended.
iii. The quantity of water used.
iv. The mixing work method.
v. Type of admixture used.
vi. Quality and type of the formwork
vii. The way of compacting the mixed concrete

2.3 CEMENT

Cement is a material that used in construction as a binder because cement has hardening properties and can bind other material at the same place. In Malaysia several types of the cement used in construction such as:

i. Portland Cement (PC)
ii. Sulphate Resisting Portland Cement (SRPC)
iii. Rapid Hardening Portland Cement (RHPC)

2.3.1 Ordinary Portland Cement

Ordinary Portland Cement (OPC) is the common cement used in construction at Malaysia. It is a basic ingredient of concrete, mortar and plaster construction. British engineer, Joseph Aspdin mepaten Portland cement in 1824, and it was named for the limestone cliffs on the island of Portland Isle of Portland in England due to its color, resembling stone quarried in situ. It consists of a mixture of calcium oxide, silicon dioxide and aluminum oxide (Thomas 2000b)

High temperature applications, such as oven bricks and the like, will normally require the use of concrete reflection, because Portland cement-based concrete can be destroyed or damaged by high temperatures, but the concrete refractory (refractory concretes) are able to with stand such conditions.

2.3.2 Type of Portland Cement

For the type of Portland cement has two major standards are the American Society for Test Material 150 (ASTM C150,2012) used primarily in the United State (USA) and European (EN 197). In Malaysia the Portland cement used must fulfill ASTM C150. The ASTM has five type of Portland cement there are designed type I to V. the table below showed the general characteristics of these type of Portland cement (Jeff Thomas, 2000). Table 2.1 shows the type of Portland cement according to ASTM 150.

Table 2.1: Type of the Portland Cements

Type	Classification	Characteristics	Applications
I	General purpose	Fairly high C_3S content for good early strength development	General construction (most buildings, bridge, pavements, precast units and etc.)
II	Moderate sulfate resistance	Low C_3S content (<8%)	Structure exposed to soil or water containing sulfate ions.
III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
IV	Low heat of hydration (slow reaction)	Low content C_3S (<50%) and C_3A	Massive structure such as dams, now rare
V	High sulfate resistance	Very low C_3A content (<5%)	Structure exposed to high level of sulfate ions.
White	White color	No C_4AF , low MgO	Decorative (otherwise has properties similar Type I)

Source: http://iti.northwestern.edu/cement/monograph/Monograph3_8.html

In Malaysia, Portland cement is known as common or general-purpose cement. It is generally assumed unless another type is specified. It is commonly used for general construction especially when making precast and precast-pre stressed concrete that is not to be in contact with soils or ground water. The typical compound compositions of this type are 55% (C_3S), 19% (C_2S), 10% (C_3A), 7% (C_4AF), 2.8% MgO, 2.9% (SO_3), 1.0% ignition loss, and 1.0% free CaO. A limitation on the composition is that the (C_3A) shall not exceed 15% (Jeff Thomas, 2000)

2.3.3 Chemical Composition of Portland Cement

The chemical compounds of the Portland cement one of the factor that effects the hydration the concrete. The chief chemical components of ordinary Portland cement are 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 by products. Table 2.2 showed the basic composition in the PC (Thomas, 2000)

Table 2.2: Basic Composition in PC

Oxide Content	%
CaO	60.2-77.3
SiO_2	18.6-23.4
Al_2O_3	2.4-6.3
Fe_2O_3	1.3-6.1
MgO	0.6-4.8
P_2O_5	-
TiO_2	-
Na_2O	0.05-1.20
K_2O	(Na_2O equiv)
SO_3	1.7-4.6

Source: http://iti.northwestern.edu/cement/monograph/Monograph3_6.html

The chief compound which usually form in process of mixing of the concrete by using the OPC are:

i. 1-Triclcium Silicate ($3CaO.SiO_2$)
ii. 2-Dicalcium Silicate ($2CaO.SiO_2$)
iii. 3-Tricalcium Aluminates ($3CaO.Al_2O_3$)
iv. 4-Tetracalcium Aluminoferrite ($4CaO.Al_2O_3.Fe_2O_3$)

2.4 WATER

In concrete work water is the most importance material. Three roles of the water in the concrete work are:

i. Water spreading cement that every particle of aggregate covered tightly.
ii. Water makes the easy to work on concrete (easy to mix the concrete).
iii. Water is an agent of the chemical reaction in the cement to bind all the aggregate in mix concrete.

Free water/cement water ratio (water to cement ratio) is the main factor to determining the strength of the concrete.

2.5 AGGERAGATE

A mixture of water and cement hardened and strengthened in a particular period. To get an economical and practical solution, the coarse and fine aggregate used for forming the bulk of the concrete mix. Sand, pebbles and gravel are the main materials used for this purpose. However, it is increasingly common for recycled aggregates (from construction waste, demolition and demolition) to be used as part replacement of natural aggregates, while part of aggregate industrial byproducts, including slag (waste) blast furnace cold air (air-cooled blast furnace) and bottom ash are also permitted. Sand and fragments of stone aggregates are commonly used in the concrete mix. It is usually divided into two groups:

i. The fine aggregate or sand: Stone aggregates of a size not exceeding 5mm. It is available from the sand mine, quarry or river.
ii. Coarse aggregate: size between 5-50 mm. It is usually obtained from quarries.
iii. Stone-frosted content is 60-80% of the volume of concrete.

2.6 PALM OIL FUEL ASH (POFA)

Oil palm was first introduced to Malaysia as an ornamental plant in 1870. Since 1960, planted area had increased at a rapid pace. In 1985, 1.5 million hectares were planted with palm tree, and it had increased to 4.3 million hectares in 2007 (Abd Razak et al. 2013). It has become the most important commodity crop in Malaysia. As of 2011, the total planted area was 4.917 million hectares. Palm oil fuel ash (POFA) is by product obtained by burning of the solid waste material like fiber, shells and empty fruit braced from as fuel in palm oil mill boilers. These solid wastes were used as a fuel to produce steam for generating the electricity of the palm oil extraction process. Since the palm oil is one of major raw material used in produce bio-diesel, it likely that the production of POFA increase every year.

2.6.1 Properties of POFA

The characteristics of the palm oil fuel ash before and after treatment were monitored to assess the changes in the properties of the palm oil fuel ash. The resulting ultrafine palm oil fuel ash was then utilized to produce high strength concrete by replacing the ordinary Portland cement at 0, 20, 40 and 60% on mass-for-mass basis.(Zeyad et al., 2012). The utilization of the ultrafine palm oil fuel ash in high strength concrete was observed to improve workability especially at higher ultrafine palm oil fuel ash content.

In addition, the long-term compressive strength of the high strength concrete was significantly increased with the ultrafine palm oil fuel ash inclusion. Palm oil fuel ash as the mentioned earlier is a waste product obtained in the form of ash on burning palm oil. Table 2.3 showed the physical properties and chemical composition of OPC and POFA that based on the POFA take from the Golden Hope Palm Oil Mill at Bukit Lawang, Johor (Abdul Awal et.al, 2011).

Table 2.3: Physical Properties and Chemical Composition of OPC and POFA

Tests	OPC	POFA
Physical properties		
Fineness - Sp. Surface area (m^3/kg)	315	520
Soundness – LeChatelier method (mm)	1	1
Specific gravity	3.28	2.22
Chemical composition (%)		
Silicon dioxide (SiO_2)	20.20	43.60
Aluminum oxide (Al_2O_3)	5.70	11.40
Ferric oxide (Fe_2O_3)	3.00	4.70
Calcium oxide (CaO)	62.50	8.40
Magnesium oxide (MgO)	2.60	4.80
Sulpur trioxide (SO_3)	1.80	2.80
Sodium oxide (Na_2O)	0.16	0.39
Potassium oxide (K_2O)	0.87	3.50
Loss on ignition (LOI)	2.70	18.00
28-day strength activity indec with OPC	-	112

Source: Abdul Awal and Warid Hussin (2011)

2.7 HEAT IN CONCRETE

The temperature of the cement because of the hydration process is generally controlled by material and mixing properties and also by natural elements. In facts, the rate of the hydration relies on upon the chemical behavior compound and nearly equal to the sum of the heat of hydration of individual unadulterated compound when their separately. Again the major constituent of OPC is calcium; therefore the development of total heat will surely effected by the amount of the material used during the mix.

As heat released by the cement is a result hydration, admixture. Other factor is water reduce or used the different material like nitrogen as the binder in the mix concrete to control the rate the rate of hydration will obvious influence the rate of the heat release (Gajda et.al,2002).