THE EFFECT OF POFA AS A CEMENT REPLACEMENT MATERIAL TOWARD THERMAL INSULATION OF AERATED CONCRETE

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ABSTRACT

Malaysia is one of the biggest countries of palm oil producer and exporter in the world. Millions tonnes of industrial waste such as palm oil fuel ash (POFA) is being produced every year with no commercial return on it. Base on pozzolanic behaviour possessed by POFA, it is necessary when POFA is being processed and used in the production of lightweight foamed concrete (LFC). Thus, the main focus of this research is to study the effect of palm oil fuel ash (POFA) towards water absorption, permeability and thermal conductivity of foamed concrete with 1200 kg/m^3 density. There are four type of foamed concrete were prepared namely i) POFA-0 with 100 % cement content, ii) POFA-1 with 10 % POFA replacement of cement content, iii) POFA-2 with 20 % POFA replacement of cement content and iii) POFA-3 with 30 % POFA replacement of cement content. The specimens were water cured before being test. The result shows POFA-2 with 20 % POFA replacement of cement content produced highest compressive strength with 17.27 Mpa for 7 days curing period, 20.89 Mpa for 28 days curing period and 29.2 Mpa for 60 days curing period while thermal conductivity gives the lowest result which is 0.59 W/mk. As conclusion, 20 % of POFA replacement by total cement weight is an optimum percentage that is suitable to be used as pozzolanic replacement material of lightweight foamed concrete in industrial construction as this material is economic and environmental friendly

ABSTRAK

Malaysia merupakan satu daripada negara yang terbesar dengan pengeluar dan pengeksport minyak sawit di dunia. Berjuta-juta tan sisa industri seperti minyak kelapa sawit abu (POFA) yang dihasilkan setiap tahun dimana bahan ini tidak mempunyai nilai komersial. Berdasarkan sifat pozzolana yang wujud dalam POFA menyebabakan bahan ini berpotensi digunakan sebagai bahan gantian didalam pengeluaran konkrit ringan berbusa (LFC). Oleh itu, fokus utama kajian ini adalah untuk mengkaji kesan bahan bakar minyak sawit abu (POFA) terhadap penyerapan air, kebolehtelapan dan kekonduksian haba konkrit berbusa dengan ketumpatan 1200 kg/m^3. Terdapat empat jenis konkrit berbusa telah disediakan iaitu i) POFA-0 dengan 100 % kandungan simen, ii) POFA-1 dengan 10 % gantian POFA dari kandungan simen, iii) POFA-2 dengan 20 % gantian POFA dari kandungan simen dan iii) POFA-3 dengan 30 % gantian POFA dari kandungan simen. Spesimen direndam didalam air sebelun ujian dijalankan. Keputusan ujikaji menunjukkan bahawa POFA-2 dengan 20 % gantian POFA dari kandungan simen menghasilkan ujian kekuatan mampatan tertinggi berbanding dengan yang lain dengan 17.27 Mpa untuk 7 hari tempoh rendaman, 20.89 Mpa untuk 28 hari tempoh rendaman dan 29.2 Mpa untuk 60 hari tempoh rendaman manakala kekonduksian haba memberikan hasil yang paling rendah iaitu 0.59 W/mk. Dengan keputusan ini, 20 % daripada gantian gantian POFA terhadap simen adalah peratusan yang optimum dan sesuai untuk digunakan sebagai bahan pengganti simen yang mempunyai sifat pozzolana ke dalam konkrit ringan berbusa dalam industri pembinaan kerana bahan ini adalah ekonomi dan mesra alam sekitar

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LIST OF SYMBOLS

Sc	Compressive strength
p	Load
k	thermal conductivity
Q	Heat conduction
H	Thickness of specimen
A	Cross-section area
T_1	Temperature of hot plate
T_2	Temperature of cold plate
m	Mass
c	Specific Heat Capacity
T	Time

LIST OF ABBREVIATIONS

Al_2O_3	Aluminium Oxide
ASTM	American Society of Testing Materials
AS_2O_3	Arsenic Trioxide
BS	British Standard
CaO	Calcium Oxide
$CaCl_2$	Calcium Chloride
$CaCO_3$	Calcium Carbonate
$Ca(OH)_2$	Calcium Hydroxide
Cl^-	Chloride
CO_2	Carbon Dioxide
Cr_2O_3	Chromium Oxide
Fe	Iron
Fe_2O_3	Iron Oxide
$Fe(OH)_2$	Iron Hydroxide
H_2O	Water
K_2O	Potassium Oxide
MgO	Magnesium Oxide
MnO	Manganese Oxide
MoO_3	Molibdenum Trioxide
MS	Malaysian Standard
NaCl	Sodium Chloride
Na_2O	Sodium Oxide
Nb_2O_5	Neobium Pentoxide
NiO	Nickel Oxide
OCP	Open Circuit Potential
OPC	Ordinary Portland Cement
POFA	Palm Oil Fuel Ash
P_2O_5	Phosphorus pentoxide
SCE	Saturated Calomel Electrode
SiO_2	Silica Oxide
SO_3	Sulfhur Trioxide

SrO	Copper Oxide
TiO_2	Titanium Oxide
Y_2O_3	Yttrium Oxide

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Concretes can be defined as composite material produced by combination between cement, usually Portland cement, mixed with fine aggregate (such as sand) coarse aggregate (granite), and water. The structure and composition of the cement paste determine the long term performance of concrete and the durability of concrete (Bertolini, Elsener Pedeferri and Polder, 2004).

Aerated concrete is relatively homogeneous when compared with normal concrete that does not contain aggregate phase. The properties of aerated concrete depend on its microstructure and composition influenced by the type of binder used, methods of curing, and pore-formation (N. Narayanan, K. Ramamurthy, 2000)

Portland cement is widely used in producing concrete, many modern concretes contain various added solid components and can be used to make concrete become more durable. Generally, it will reduce the alkali hydroxide concentration produce in concrete. The incorporation of POFA as a replacement cement material in concrete exerts has a very strong influence in reducing permeation capacity, although not necessarily to the same extent in different type of measurement. Palm oil fuel ash (POFA) was used as a pozzolanic material in concrete.

POFA is a by-product from biomass thermal power plants where oil palm residues are burned to generate electricity. The physical properties and chemical properties analysis of POFA show that POFA is a pozzolanic material that can be used as a cement replacement material (Sumadi and Hussin, 1995)

However, green building that provide better thermal insulation has caught eyes researcher to investigate thermal conductivity of concrete. Concrete has the characteristic that depend on porosity and moisture which affect the thermal conductivity. Therefore, Aldridge, (2005) described that the low thermal conductivity will produced high thermal insulation as it is ability to resist the flow of heat while making foamed concrete six times more thermal efficient. Advantages for light weight foamed concrete with very low density that can be used as thermal and sound insulation panels, filtering media and floating blocks for fishery purpose.

A research from Faculty of Civil Engineering of University Technology Malaysia successfully discovered that POFA can be considered as replacement materials that are actually used in a construction industry specifically in concrete engineering. The POFA usage in concrete production continues to be studied by researcher in Asian because the waste from palm oil mill is widely discovered in Asian region.

1.2 PROBLEM STATEMENT

A concrete structure is considered to be of durability if it performs in accordance with its intended level of functionality and serviceability over an expected or predicted life cycle. Durability concrete must have the ability to withstand the potentially deteriorative conditions to which it can reasonably be expected to be exposed. The concrete has a weakness of characteristic and POFA is a cement replacement to make it the concrete can be more durability as well. POFA is a recycle material and got from factory. That is three methods to measure characteristic of concrete, for example used the thermal insulation method for measure temperature.

Malaysia has large number of palm oil waste producer and exporter in the world. This concern towards preserving POFA for future generation has lead to increase the integrating POFA as partial cement replacement in concrete material. Besides, influence of POFA introduce air void that affect the thermal conductivity. Thermal insulation material is one of the green building properties and incorporative POFA is friendly environmental.

According to T.Yun, Y.Jeong, T.Han et al (2007). Passive energy-saving houses and buildings made of thermally insulated materials become popular in recent construction practices to address the demanding energy needs and to reduce the consumption of hydrocarbon energy resources. Thermally insulated concretes represent alternative construction materials to improve the thermal efficiency in a wide range of residential and commercial buildings.

With growing concern in the past decade over complaints attributes to poor quality of concrete due to the durability especially in aerated problem in concrete structure, various environmental parameters and testing were suggested to improve the quality of concrete composite. The pozzolanic material used for reducing the Portland cement content in mortar and concrete paste. The testing include of water absorption, permeability and thermal conductivity.

1.3 OBJECTIVE OF STUDY

The objectives of the study are:

i. To determine the effect POFA as cement replacement material toward water absorption and porosity

ii. To determine the effect of POFA toward permeability.

iii. To determine the effect of POFA toward thermal insulation and thermal conductivity.

1.4 SCOPE OF STUDY

The purpose of this research is to study the performance of POFA as a cement replacement due to the aerated concrete and the investigation is going to be done by comparing the plain concrete with 0 % of cement replacement and 10 %, 20 %, 30 % respectively that consist of POFA as a replacement ingredient to concrete.

For this study, the strength of the concrete will be determined using water absorption test in aerated concrete because there is a strong interaction with water. Permeability testing is a potential for moisture and ion in concrete modes is referred to as permeability. On the other hand, the same proportion of cube was prepared and cured in water for one day and air dried for a day or until the moisture removed. Then, the thermal conductivity test was conducted by considering the differences temperature between hot surface and cold surface

This research will be conducted at Concrete Laboratory in University Malaysia Pahang (UMP). The density of concrete for this experiment is between 1000kg/m^3 - 1200 kg/m^3.

1.5 SIGNIFICANT OF STUDY

Since the last decades, concrete plays an important part in construction. Many modifications and developments have been made to place industrial waste such as concrete itself and waste material like POFA as a cement replacement. This research is to investigate and propose the significant of the replacement POFA as a cement material. The energy use in the residential buildings can be reduced.

The significance of study are:

i. To reduce the usage of cement content by replacing palm oil fuel ash as a cement replacement in aerated concrete

ii. To reduce waste from palm oil mill.

iii. To reduce the use of electricity

iii. To create new product from palm oil industry and increase economy of country.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Concrete is the material composition that widely used in construction field. This is the mixture of course aggregate, fine aggregate, cement and water. Concrete nowadays changing better by adding with pozzolanic material such as silica fume, fly ash and palm oil fuel ash in order to make it stronger in durability due to pozzolanic reaction occur in concrete mixes.

The development and used of blended cement are widely raised in construction industry mainly due to the consideration of cost saving, energy saving, environmental protection and conservation of resources (Tae-Hyun Ha et. al., 2007).

The usage of POFA in mortar and concrete as a partial replacement of Portland cement appears to constitute a very satisfactory outlet for this industrial by product. The POFA are used to substitute a portion of a cement give positive result in saving cost of production of concrete (Tae-Hyun Ha et. al., 2007).

POFA have a potential become a good replacement material comparing to other waste because it contains siliceous compositions and reacted as pozzolans to produce a stronger and denser concrete. There are many experimental works conducted by introducing recycled material likes palm oil fuel ash (POFA) as a replacement of the cement with different percentages to improve the properties of concrete.

2.2 CONCRETE INGREDIENT

Concrete has been the construction material used in the large quantity for several decades besides using timber or steel materials. Concrete are popular used in the construction because of the properties of concrete itself as well as the acceptable costing. Material called concrete is made of from four basic ingredient which are course aggregate, fine aggregate, cement and water.

2.2.1 Palm Oil Fuel Ash (POFA)

Palm oil fuel ash obtained from the burning of pressed fibre and shell which are used as fuel to generate steam and energy required for the operation of mill which needs to be ground in order to improve pozzolanicity. This is because very low content of calcium oxide making it could not function without the presence of cement. However, the ash formed during open-field burning or uncontrolled combustion in furnaces generally contains a large propotion of less reactive silica minerals and must be ground to a very fine particle size in order to develop some pozzolanic activity. In addition, a highly pozzolanic ash can be produced by controlled combustion when silica is retained in noncrystalline form and a cellular microstructure that contribute strength as early as 1 and 3 days. Furthemore, POFA is produced by combustion of palm oil husk and palm kernel shell in the steam boiler which is approximately 5% of solid waste by-product, equivalent to 3.1 million tonnes in Malaysia in 2010 (Tangchirapat et al., 2007).

2.2.3 Silica Sand

Silica sand was used in making lightweight aerated concrete. The reason using silica sand is to improve the strength of concrete and to investigate the effect towards thermal conductivity. This is due to high silica composition in silica sand and the particle size is finer compare to normal or river sand. The size of silica sand use was less than 0.3 mm.

2.2.4 Fine Aggregate

Typically example of fine aggregate used in concrete mixes is sand. Fine aggregate mostly comes in a small particles compared to course aggregate. The dividing line between coarse aggregate and fine aggregate is arbitrary.

2.2.5 Portland Cement

Portland cement has become a most important ingredient in construction material and it is one of the primarily material in concrete mixes. Portland cement is produce from combination between limes containing material such as lime stone. Typical tiny Portland cement numerous microscopic crystals called clinker minerals also known as cement compounds. The various function of concrete need Portland cement of different properties.

2.2.6 Water

Water is used in concrete making as mixing in concrete paste, used for cutting of concrete and washing. Impurities may be either dissolved in the water or present in the form of suspensions. Some of these impurities such as sugar, tannic acid, vegetable matter, oil, and sulfates, may interfere with the hydration of the cement, thus delaying setting and reducing the strength of the concrete. These effects vary markedly with the brand and type of cement used as well as with the richness of the mixture.

2.2.7 Foam

Base on Ramamurthy, Nambiar and Ranjani, (2009), there are two type of foam in producing lightweight cellular concrete either by pre-foaming method or mixed foaming method. Pre-foaming method comprises of producing base mix and stable preformed aqueous foam separately and then thoroughly blending foam into the base mix. In mixed foaming, the surface active agent is mixed along with the base mix ingredients and during process of mixing foam is produced resulting in foam structure in concrete. According to the Koudriashoff, (1949), the foam must be firm and stable so that it resists the pressure of the mortar until the cement takes its initial set and a strong skeleton of concrete is built up around the void filled with air. The preformed foam can be either wet or dry foam. The wet foam is produced by spraying a solution of foaming agent over the fine mesh, has 2-5 mm bubble size and is relatively less stable. Dry foamed is produced by forcing the foaming agent solution through a series of high density restrictions and forcing compressed air simultaneously into mixing chamber. Dry foam is extremely stable and has size smaller than 1 mm which makes it easier for blending with the base material for producing pump able foam concrete.

2.3 THERMAL CONDUCTIVITY

Thermal conductivity depends on density, moisture content and ingredients of the material (Rudnai G, Watson KL, Eden NB, Farrant JR, Laurent JP, Guerre-Chaley C, Loudon AG, Valore RC, Richard TG, 1963). As thermal conductivity is largely a function of density, it does not really matter whether the product is moist cured or autoclaved as far as thermal conductivity is concerned. The amount of pores and their distribution are also critical for thermal insulation (Bave G.1980). Finer the pores better the insulation. Valore RC. (1956) stated that as the thermal conductivity (a 1 % increase 42 % -RILEM), it should not be reported in oven dry condition. Based on the thermal performance requirements for buildings, an optimum material design has been proposed by Tada

2.4 AERATED CONCRETE

Richard Cabrillac (2006), the aerated concrete manufacturing process consists in the creation of macro porosity in a micro-mortar matrix with the help of an expansive agent (aluminum powder), which reacts with the water and the lime liberated by the hydration of the binder. Theoretical studies previously conducted on the idealization of aerated concrete have shown that its behavior can present mechanical and thermal anisotropies due to the configuration of the porosity (form, distribution and orientation of pores)

2.5 THE INFLUENCE OF MOISTURE CONTENT OF CONCRETE

Besides, availability of oxygen in the air affects the permeability of the moisture content of the concrete. Porous material such as concrete may absorb water from the air. For the absorption process and desorption processes the determining factor are the pore structure which is the void in concrete. Since the diffusion of carbon oxide is low at the high moisture content of the concrete and the carbonation reaction needs water there is a maximum rate if carbonation at a medium range of relative humidity (Houst Y F and Wittmann F H, 1994).

2.6 THE SIGNIFICANT OF POZZOLANIC REACTION BY USING POFA

Pozzolans material is the siliceous material which they themselves has no cementations properties but in finely divided form and in the present of moisture content, the pozzolans material can react with calcium hydroxide of concrete at home temperature. The reaction is called pozzolanic reaction (Mohd Eriezi, 2010).

Pozzolanic reaction that would only take place after the availability of CaOH that been produced through the occurrence of hydration process. However, water is essential for pozzolanic reaction to occur & form secondary C-S-H gel. Therefore, initial water curing is essential to ensure faster hydration process to create a large amount of lime for the occurrence of pozzolanic reaction as well.

Formation of additional C-S-H gel would fill the existing voids in concrete thus creating denser concrete. Furthermore, reduction in amount of CaOH that is vulnerable to aggressive environment improves the durability of concrete. This finally increases the strength and durability of this hardened material.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss in detail the procedure in carrying out the experimental work and laboratory test to achieve the objective as set in this project. There is a variety of testing to be carried out in this project. Sieve analysis is the first test to be carried out to testing the replacement material which is palm oil fuel ash as a cement replacement. Then, the testing to be follow by water absorption, permeability and thermal insulation test will be conducted in central laboratory.

3.2 MATERIAL USED

In order to make lightweight foamed concrete influence by POFA consist of listed raw material which are Odinary Portland Cement, POFA, silica sand, water and foam.

3.2.1 Ordinary Portland Cement

In this study was preferred to use ordinary Portland cement that available in laboratory supplied by YTL Cement Sdn. Bhd. The ordinary Portland cement used was type 1 Portland cement as followed the ASTM C150 (2005) requirement. The sample of OPC was send to chemical laboratory to be test.

Table 3.1: Chemical Composition of POFA Used in Various Researches

(Awal, 1997; Tangchirapat, 2007; Eldagel, 2008)

Chemical Composition	**Awal**	**Tangchirapat**	**Eldagal**
Silicon dioxide	43.60	57.71	48.99
Aluminum oxide	11.50	4.56	3.78
Ferric oxide	4.70	3.30	4.89
Calcium oxide	8.40	6.55	11.69
Magnesium oxide	4.80	4.23	1.22
Sulphur oxide	2.80	0.25	-
Sodium oxide	0.39	0.50	0.73
Potassium oxide	3.50	8.27	4.01
Loss of ignition (LOI)	18.00	10.57	10.51

*All values are in percentage

Figure 3.1: Ordinary Portland cement