COMPARATIVE STUDY ON THE EFFECT OF PALM OIL FUEL ASH (POFA) IN SUPPRESSING THE ALKALI SILICA REACTION FOR CONCRETE AND MORTAR

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ABSTRACT

Mortar and concrete is widely use in development of research and construction sector. The use of palm oil fuel ash (POFA) in concrete mix is due to the disadvantages that POFA brings by cause some environmental issues also to improve the durability of the concrete. Concrete is expose to Alkali-Silica reaction which can cause defect to the concrete itself by expansion. For this research study, two source of POFA is collected from two different palm oil mills and 2 types of sizes are used, unground size (300 μm) and ultrafine size (below 2 μm). The unground and ultrafine POFA are treated by burning process for one hour and two hour. First objectives for this study are to evaluate the effects of unground and ultrafine size of POFA replacement in suppressing the expansion caused by Alkali-silica reaction. Second objectives are to evaluate the effects of unburnt and burnt POFA as cement replacement in suppressing the expansion caused by Alkali-silica reaction. Last objectives are to analyze and investigate the correlation between mortar bar test and concrete prism test. Two accelerated tests are conducted in this research, ASTM C1260 for accelerated mortar bar test and RILEM AAR-4.1 for accelerated concrete prism test. Based on the result from the tests conducted, ultrafine POFA and burnt POFA (two hours treatment) is more effective in suppressing the expansion caused by Alkali-silica reaction.

ABSTRAK

Kajian perbandingan terhadap kesan abu terbang kelapa sawit (POFA) dalam mengurangkan tindak balas Alkali-silika bagi konkrit dan mortar

Penggunaan mortar dan konkrit semakin meluas dalam pembangunan penyelidikan dan sektor pembinaan. Penggunaan abu terbang kelapa sawit (POFA) dalam campuran konkrit adalah kerana bagi mengatasi kesan buruk POFA kepada alam sekitar serta membaik pulih ketahanan konkrit. Konkrit terdedah dengan ancaman tindak balas Alkali-Silika (ASR) yang boleh menyebabkan kecacatan kepada konkrit dengan cara pengembangan konkrit itu sendiri.Terdapat dua sumber POFA yang diambil dari kilang kelapa sawit yang berlainan dan dua jenis saiz POFA yang digunakan untuk kajian ini iaitu saiz kasar (300 µm) dan juga saiz halus (dibawah 2 µm). Juga terdapat tiga jenis POFA digunakan iaitu POFA yang tidak dibakar, POFA yang dibakar selama satu jam dan POFA yang dibakar dua jam. Objekif yang pertama untuk penyelidikan ini ialah untuk menilai kesan saiz POFA kasar dan halus sebagai penggantian simen dalam mengurangkan pengembangan oleh ASR.objectif yang kedua ialah utuk menilai kesan POFA yang tidak dibakar, POFA yang dibakar satu jam dan POFA yang dibakar dua jam sebagai penggantian simen dalam mengurangkan pengembangan oleh ASR .Objektif yang terakhir ialah menganalisis dan mengkaji hubungkait diantara ujian bar mortar dan prism konkrit. Dua ujian singkat telah dibuat untuk mengkaji ketahanan terhadap ASR bagi mortar dan konkrit. Ujian tersebut adalah ASTM C1260 untuk bar mortar dan RILEM AAR-4.1 untuk prisma konkrit. Berdasarkan keputusan dari kedua-dua ujian yang sudah dilaksanakan, POFA bersaiz halus dan dibakar selama dua jam lebih cenderung untuk mengurangkan pengembangan oleh ASR.

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LIST OF ABBREVIATIONS

ASR	-	Alkali silica reaction
POFA	-	Palm oil fuel ash
ASTM	-	American Standard for Testing Materials
AMBT	-	Accelerated mortar bar test
ACPT	-	Accelerated concrete prism test
OPC	-	Ordinary Portland cement
LOI	-	Loss of ignition
DEF	-	Delayed ettringite formation
mm	-	Millimetres
µm	-	Micrometers
kg	-	Kilogram
°C	-	Degree Celcius
P	-	Density
1M	-	One molar solution
NaOH	-	Sodium Hydroxide
Na_2O	-	Sodium Oxide
K_2O	-	Potassium Oxide
SiO_2	-	Silicon Oxide
CaOH	-	Calcium Hydroxide
CSH	-	Calcium Silicate Hydrate
$MgSO_4$	-	Magnesium Sulphate
Al_2O_3	-	Aluminium Oxide
Fe_2O_3	-	Iron Oxide
OH^-	-	Hydroxyl ions

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Nowadays, concrete is widely used all over the world. Concrete is used for development such as building. Human being desperately builds structure so that they can live under the structure to cover them up from rainy and sunny day. From years to years, there are a lot of drastically changes on construction sector, for example Pre-cast system. Due to the high technology, construction sector have lot of improvement especially in machinery and management.

Concrete consists of coarse aggregate, fine aggregate and cement that combined together with water that hardens over time. Concrete give a good strength and durable for a longer use but once concrete seriously affected or damaged, there are no straightforward remedies. Concrete can be affected in many ways either in mechanically/physically or chemically. For this study, it wills more on chemically attack that is alkali-silica reaction.

Alkali-silica reaction (ASR) is heterogeneous chemical reaction, which process that involves materials in different phase. ASR takes place in aggregate particles between the alkaline pore solution of the cement paste and silica in the aggregate particles. When ASR occurs, the concrete start to expand and disrupt that will produce "map cracking" on the surface o the concrete.

ASR will occurs when these three factors is exists, which are high alkaline pore solution, reactive aggregate and high moisture level in concrete. ASR can be reducing by using low-alkali cements, avoidance of reactive aggregate. Since low-

alkali cements quite expansive and it's hard to find non-reactive aggregate in certain places, the best way to reduce ASR is by adding pozzolanic materials into the concrete. Researcher come with study, found that Palm Oil Fuel Ash (POFA) have high tendency to be used as pozzolanic materials due to the high amount silicon dioxide.

POFA is used because the aggressive amounts of POFA were produced annually by oil palm mill. This is due to the high demand in oil palm product all over the world. POFA is the result from the burning process of the fibres, nutshells and empty fruit bunches. The burning process is used to generate electricity for the mill plant. In addition, POFA is dumped waste that comes with no commercial value. Thus, due to this issue, researchers try to use the agricultural waste as an admixture in construction industry, so that environmental issue such as air, water and land pollution can be avoided.

1.2 Problem Statement

1.2.1 Alkali Silica Reaction (ASR)

Alkali silica reaction (ASR) tends to be occurred when there is a high alkali property, reactive aggregate and presences of moisture. ASR can cause concrete deterioration thus tend to cause corrosion to the reinforcement steel.

High in pH value in Ordinary Portland cement (OPC) will encourage the ASR to take place in the mortar or concrete this is because cement is act as alkalis.

Non-reactive aggregate is difficult to be found in certain area, due to that reactive aggregate had to be use. In Sabah especially in Penampang, aggregate produced by the quarries is reactive aggregate (sandstones) (Asrah et al., 2015).

Thus, reaction between reactive forms silica in the aggregates and the hydroxyl ion in the alkaline cement pore solution in mortar or concrete mixes will cause ASR to be occurred by formation of reaction product which is gel that can

swell by absorbing water (Farny, 2007). The engineering properties and the durability of mortar or concrete can be affected, when ASR take place.

1.2.2 Palm Oil Fuel Ash (POFA)

When POFA were added into mixes of mortar or concrete, problems such as environmental issue can be addressed and high cost in disposal the waste material from the mill can be reduced to minimum. Due to increasing raw material such as cement also make researchers using POFA as a replacement to cement.

POFA become problems since the huge production of this waste materials because need a lot of spaces to dumped and need high cost for disposal process. Malaysia as the second largest producers of palm oil products after Indonesia in East-Asia produced a million tonnes annually.

The reuse and recycle of POFA to be used into mortar or concrete is a good way in reduce the usage of cement also to minimize the problem comes due to production of POFA itself. Studies done by researchers found that the usage of POFA gives a good and positive result especially the properties of the mortar or concrete.

The used of POFA in concrete is because of pozzolanic properties which have high silicon dioxide ($Si0_2$) in amorphous form. When the POFA is improved in size, it will give cementing property which is as supplementary cementatious material in mortar or concrete. POFA can give high strength because POFA can reduce the porosity in the bulk and inter-facial zone because POFA have ability to generate the secondary hydration which is formation of additional calcium silicate hydrate (C-S-H). Thus, C-S-H will lead to decreasing of porosity.

1.3 Objectives

Objectives for this research are:

a) To evaluate the effects of unground and ultrafine size of POFA replacement in suppressing the expansion causes by alkali silica reaction.
b) To evaluate the effects of unburned, one hour and two hour treatment of POFA as replacement in suppressing the expansion causes by alkali silica reaction.
c) To investigate and analyse the correlation between mortar bar and concrete prism test based on expansion.

1.4 Scope of Work

All the studies and tests for this research is to investigate the performance of non-treated and treated ultrafine of POFA in preventing expansions by the ASR.

Materials were collected from local sources. For coarse aggregate, sample was taken from Moyog quarry, Penampang. Then for POFA, it was taken from two different mill, which is from Langkon mill, Kota Marudu and Lumadan mill, Beaufort.

Material testing such as specific gravity and absorption were conducted for determines the specific gravity and percentage of water absorption for coarse and fine aggregate. The, density of the POFA is determined by using density test of hydraulic cement, ASTM C188. The average size of the ultrafine POFA is is determined by using particle size analyse and the morphology of the POFA is illustrated using scanning electron microscopy (SEM). Spectroanalytical procedure such as atomic absorption spectroscopy (AAS) is conducted to determine the chemical elements using the absorption of optical radiation. Also, the aggregate is prepared using polarizing petrographic microspcope for Thin Section Petrography. Next, Accelerated Mortar Bar test, ASTM C1260, for mortar testing and RILEM recommended test method, AAR-4.1, for detection of potential alkali reactivity on concrete prism.

The size of POFA used for the mortar and concrete is unground size which is average size of 300 µm while for the ultrafine size is below 2 µm. to prepare the unground POFA, the collected POFA is dried in open air for one day after that dried in oven for 24 hours to remove the excess moisture. After that, the POFA will be sieved using 600 µm and 300 µm sieve. POFA should pass the 600 µm sieve and retained at 300 µm sieve.

There are two methods used to get the ultrafine size of POFA. First by using the Los Angeles abrasion machine with 12 mm diameter and 450 mm length of stainless steel rod were used. Every batch of grinding, 26 stainless steel rod is used for four kg of unground POFA and the machine were rotated at 30, 000 cycles. Second method is by using planetary grinding mill that only took about 2 hours to achieve ultrafine size. But before using the planetary grinding mill, POFA need to be grinded 500 cycle using Los Angeles abrasion machine. This is for uniformity. From both methods, the size of POFA is below 2 µm as a result.

For period of treatment, POFA is treating at one hour and two hour of burning process using furnace. 1.2 kg of POFA is treated at one time of treatment using 16 L of furnace machine. POFA burned in the container should not be too thick or thin. This is for uniformity of burning of the POFA particles. POFA is burnt at 500 °C.

For accelerated Mortar Bar test (ASTM C 1260), the mortar bar will be immersed in sodium hydroxide (NaOH) solution at 80°C ± 5 to accelerated the reaction of ASR for 28 days and expansion of the mortar bar will be measured at day 1^{st}, 3^{rd} , 7^{th} , 14^{th} ,21^{st} and 28^{th}.

For concrete prism test, RILEM recommended test method, AAR-4.1, the concrete prism is mixed with NaOH in mix design. The concrete prisms were stored in 60 °C to accelerate the reaction of ASR to be occurred. The concrete prism will be tested on expansion and weight checking at day 28^{th}, 56^{th}, 91^{st}, 126^{th} and 182^{nd}.

1.5 Importance of Study

This study related to the research purpose and related to the real life situation especially in construction. Since in real life situation, concrete have been used, thus concrete is being tested in this study. Mostly, researchers study on the engineering properties of the concrete especially the strength. Study on durability of concrete still few in number compared to engineering properties.

The utilization of POFA in mortar or concrete becomes wider. This is because investigation and study on ultrafine POFA (uPOFA) still few in number. So, research on this waste material need further study. Also, study on non-treated and treated ultrafine of POFA is least.

In addition, replacement of cement with POFA is one of the better ways to maximize the recycling and reuse the waste material. Due to the increasing environmental problems on reducing the waste material and pollution can be reducing by using the waste material in construction industry. Thus, it is a good way to communicate and cooperate with different area. But replacement of cement is limited to certain percentages to ensure the strength of concrete or mortar is acceptable.

Thus, by using POFA as replacement of cement can reduce and may prevent expansions to mortar or concrete that cause by the alkali silica reaction to be occurred. Beside that, the excessive amount abundant waste material can be reduced and cost on disposal process can be reduced too.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Alkali-Silica reaction (ASR) is a heterogeneous chemical reaction which takes place by the reactive silica in aggregate and the alkalis (Na_2O and K_2O) within cement paste, as a result alkali gel is formed (Yurtdas, Chen, Hu, & Shao, 2013). The ASR is reactions that occur over time in concrete and mortar. ASR can be reduced by replaced cement with palm oil fuel ash (POFA) in percentages of replacement. Test results on the effectiveness of POFA that revealed by Awal and Hussin (1997) found that POFA had a good potential in reducing the expansions due to the ASR. After that Awal and Hussin (1998) studied the expansion of mortar mixed with 30% POFA and found that expansion of mortar due to sulphate attack is reduced.

Malaysian Palm oil Council (MPOC) stated that Malaysia currently accounts for 44% of world exports and 39% of world palm oil production that makes Malaysia as the second largest palm oil producer after Indonesia. POFA is a secondary waste from the palm oil mill. Palm oil mill in Malaysia produced POFA and dumped these waste without any profitable return (Sumadi & Hussin, 1995). POFA were dumped at the plantation area due to the no profit return (Tay, 1990), but due to pozzolanic properties, POFA can be used as a replacement of cement in normal concrete (Yusuf et al., 2014).