



INVESTIGATION OF MECHANICAL PROPERTIES ON CEMENT PASTE FILLED WITH PALM OIL FUEL ASH (POFA)

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**MASTER OF MANUFACTURING ENGINEERING
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Faculty of Manufacturing Engineering

**INVESTIGATION OF MECHANICAL PROPERTIES ON CEMENT
PASTE FILLED WITH PALM OIL FUEL ASH (POFA)**

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Master of Manufacturing Engineering (Manufacturing System Engineering)

2019

DECLARATION

I declare that this thesis entitled “Investigation of Mechanical Properties on Cement Paste Filled With Palm Oil Fuel Ash (POFA)” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Manufacturing System Engineering).

Signature :

Supervisor Name : Dr. JEEFFERIE BIN ABD RAZAK

Date :

DEDICATION

To my beloved mother, father and wife who supported me a lot
through the years.

ABSTRACT

Investigation on impact strength and compressive strength attribute of cement paste filled with palm oil fuel ash (POFA) based pozzalonic composites was performed in this research. In order to preserve the environment for future sustainability, the idea of mixing natural waste material in their original form is something that could be a brilliant idea for designing a sustainable based product innovation. Thus, POFA been added into cement paste rather than by just mixing of only cement with water and sand to create concrete, could be the smart way to establish an improvement for both impact and compressive strength of the resulted cured cement. The main objectives of this study are to evaluate the effect of curing days and amount of POFA added into the composite mixture and examine their resulted impact strength and compressive strength of produced specimen. A combination of mixing cement with varied percentages of POFA (0%, 10%, 20% and 30% by wt %) and sand into cement portion (2:3 ratio) and fixed amount of water content of 0.4 were carried out in order to determine the impact strength and compressive strength for the pozzalonic composites. This has applied different number of curing days of 7, 14, 21 and 28 days of curing periods in order to determine the most optimum parameter of curing duration since curing day's gives prominent effects to the mechanical properties of prepared samples. Also, this research investigated the correlation between strength with resulted composites microstructure by using the Scanning Electron Microscope (SEM). In addition, the Rockwell Hardness test, water absorption test and density test also conducted to investigate the physical state of cement paste composites filled with POFA. From this study, C/POFA 1 (90/10 wt. % of cement/POFA) composite with prolonged curing duration leads into significant improvement of resulted mechanical properties of produced composites. The use of POFA as a cementitious material could replace small amount of cement paste utilization that absolutely can help on preserving concrete mineral resource, lowering cement paste cost and last but not least, provide another candidate of advanced materials derived from natural waste.

ABSTRAK

Peyelidikkan mengenai kekuatan daya hentaman dan sifat kekuatan mampatan terhadap campuran simen dengan komposit pozzalonic berasaskan abu dari bahan api kelapa sawit (POFA) telah dikaji dalam penyelidikan ini. Untuk memelihara alam sekitar bagi kelestarian masa depan, idea pencampuran bahan buangan semula jadi dalam bentuk aslinya adalah sesuatu yang boleh menjadi idea yang baik dalam merekabentuk inovasi produk. Untuk kajian ini, POFA dicampurkan ke dalam pes simen boleh menambahbaikkan kekuatan daya hentaman dan sifat kekuatan mampatan komposit. Objektif utama kajian ini adalah untuk menilai kesan pengeringan hari dan jumlah POFA yang ditambah ke dalam campuran komposit dan mengkaji kekuatan daya hentaman dan kekuatan mampatan bagi spesimen yang dihasilkan. Gabungan simen dengan peratusan variasi POFA (0%, 10%, 20% dan 30% dengan% wt) dan pasir dengan nisbah 2: 3 serta jumlah nisbah kandungan air yang tetap sebanyak 0.4 telah dijalankan untuk menentukan kekuatan daya hentaman dan kekuatan mampatan untuk komposit ini. Kajian ini telah menggunakan 7, 14, 21 dan 28 hari untuk tempoh pengeringan bagi menentukan masa pengeringan yang memberi kesan paling optimum kepada sifat mekanikal yang dikaji berdasarkan kepada spesimen yang telah dihasilkan. Selain itu, kajian ini telah mengkaji hubungkait antara kekuatan dengan mikrostruktur komposit yang dihasilkan dengan menggunakan Mikroskop Pengimbasan Elektron (SEM). Di samping itu, ujian kekerasan Rockwell, ujian penyerapan air dan ujian ketumpatan juga dijalankan untuk menyiasat keadaan fizikal komposit yang dicampurkan dengan POFA. Dari kajian ini, C/POFA 1 (90/10 wt.% simen /POFA) komposit yang dihasil dengan tempoh pengeringan yang berpanjangan menunjukkan penambahbaikan terhadap sifat-sifat mekanikal. Penggunaan POFA boleh mengurangkan penggunaan simen disamping boleh membantu memelihara sumber mineral, mengurangkan kos simen dan terakhir menguna semula bahan yang berasal dari sisa semulajadi.

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LIST OF ABBREVIATIONS

POFA	-	Palm Oil Fuel Ash
EFB	-	Empty Fruit Bunches
POS	-	Palm Oil Shells
C-S-H	-	Calcium-Silicate-Hydrates
OPC	-	Ordinary Portland Cement
ASTM	-	American Society For Testing And Materials
SiO ₂	-	Silicon Dioxide
Al ₂ O ₃	-	Aluminium Oxide
Fe ₂ O ₃	-	Iron Oxide
CaO	-	Calcium Oxide
SO ₃	-	Sulfur Trioxide
CCA	-	Corn Cob Ash
PPLA	-	Pawpaw Leaf Ash
NDT	-	Non-Destructive Tests
FKP, UTeM	-	Faculty of Manufacturing Engineering, Universiti Teknikal Melaka

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nowadays, the use of cement is essential for the rapid urbanization all around the world. Portland cement is one of the most versatile and extensively used man-made construction materials worldwide (Lai, 2015). It is considered as a key element in social, economic and infrastructural development because cement and concrete are vital construction materials in building for many mega infrastructures such as buildings, sky-scrappers, roads, culverts, bridges, flyovers, tunnels, river protection structures and railways. In the past few years, many research and modification has been done to produce cement paste based composite which has the desired characteristics. There is always a search for cement paste composite with higher strength and long-term durability.

Cementitious materials known as pozzolanic materials are used as cement paste composite constituents, admixture to Portland cement. Originally the term pozzolanic was associated with naturally formed volcanic ashes and calcined earths will react with lime at ambient temperatures in the presence of water (Jennifer, 2017). The use of fly ash in cement paste composites as admixture has gained significant consideration due to its beneficial effects on the modified composites (Roychand, 2016). Numerous researchers has also been performed

on cement paste composites modified by the addition of fly ash for improved properties, allowing high volumes of fly ash to be incorporated, with enhanced strength development. Current development in cement paste based composites has involving the role of additive filler from naturally origin resources, to reinforce their resulted properties. Some of the natural resources has yielded from the waste crops or vegetative plants such as palm oil, rubber tree, kenaf and many more. However, for this research, the potential of palm oil fuel ash (POFA) from waste or dead palm tree will be evaluated as functional filler for pozzalonic based composite materials.

Referring to Din (2016), there are about 429 palm oil industries in Malaysia which has an annual capacity of 102 million tons. Palm oil fuel ash (POFA) is one of the most abundantly produced waste materials generate form this industry. POFA is a solid waste produced from the palm oil industry through the combustion of fibers, shells and bunches (Sata, 2007).

According to Deepak et al. (2014) POFA is an agricultural waste of palm oil residue from which palm fiber and shells are procured. They are burnt at 800 °C to 1000 °C which thermally generate the electricity. POFA is a pozzolanic material, which has the highest percentage of alumino-silicate content (Oyeleke, 2011). On the other hand, Tangchirapat (2007) has stated that the finer size of POFA possessed better reaction with cement paste, thus produces concrete that having resulted strength higher than the coarser size of POFA added.

Besides reducing the amount of solid waste in the environment, the incorporation of POFA as a cement replacement would also reduce the emission of greenhouses gaseous. When POFA is used as a cement replacement, the total cement usage could be reduced. Hence, the production of carbon dioxide during cement manufacturing is also drastically reduced. Carbon

dioxide is a major greenhouse gas that responsible for global warming (Sadia, 2017). Therefore, utilization of POFA as a cement replacement would result in a cleaner environment.

In this research, the effects of POFA addition into the cement paste based composites will be evaluated in terms of their resulted mechanical, physical and microstructural properties. Among importance parameters that will be varied are on the POFA filler loadings and curing time, which ranging into the standard curing period at normal practice. Correlation between the resulted physical and mechanical properties with the microstructural observation of resulted composites will be established in this study.

1.2 Problem Statement

Cement-based materials are the most abundant manufactured materials, worldwide. In an ideal setting, cement is an important material in construction that are used as binder for strength and durability of concrete. Jin (2013) had identified green concrete as concrete produced by utilizing alternative or recycled waste materials in order to decrease energy consumption, environmental impact and natural resource consumption. In other words, the concrete which is made from waste eco-friendly material and environmentally friendly are called as green concrete (Elson, 2017). In this research, the green concrete made of cement paste filled with POFA will be produced and characterized, further.

Palm oil industry is among the most important industries and there are 429 palm oil industries in Malaysia (Din, 2016). POFA is widely produced by the oil palm industry owing to the burning of empty fruit bunches (EFB), fiber and palm oil shells (POS) as fuel to generate electricity and the waste, collected as ash, becomes POFA (Shahram, 2015). Recent research

done by Sadia (2017) found that POFA had pozzolanic characteristic and function as a cementitious material and is suitable for replacing cement in common concrete formulation. The purpose of this research is to reduce the utilization of cement in concrete by mixing it with POFA which is a natural waste resource that usually discarded. In addition, to make the POFA that is natural waste into a useful material is by creating composite which admixture into cement composition.

To determine the composite effectiveness, a study on impact and compression strength behaviour of this composite been performed. Knowing the value of impact would help in finding the amount of the blow energy that would cause fracture to the concrete and also energy that is minimally required to cause the concrete to experience failure. The impact test result and compressive strength were significantly important in knowing the strength of the concrete that are able to withstand, when it being blasted and also the main interest in military and civil application which is why it is used as the main response in the study.

1.3 Objectives

For future research development in the idea of combining pozzolonic material with natural waste is finding the best mixing parameter and suitable composition in order to create better cement paste based composite. Therefore, in order to achieve this aim, the objectives of this study are stated as in the followings:

- i) To prepare the cement paste reinforcement with palm oil fuel ash (POFA) composite at different filler loadings addition.

- ii) To evaluate the effect of curing periods and POFA loadings on the impact strength, Rockwell hardness, compressive strength, percentage water absorption and density properties of produced composite (C/POFA composites).
- iii) To correlate the resulted microstructural observation of C/POFA composites observed by using Scanning Electron Microscope (SEM), with their physical and mechanical properties attributes.

1.4 Research Scope

With the idea in creating new product that goes for sustainable development and environmental friendly material, by mixing material of natural waste (POFA) with cement gives significant effect even small towards environment. The material would be specific type of cement that was sold in nearest marketplace which was YTL cement (Castle: Portland Composite Cement, certified to MS 522-1: 2007 CEM II / B-L 32.5N) and POFA used in this study was collected from a local palm oil mill located in Rompin, Pahang. This research is experimental type research by controlling the variable in order to find the impact strength and compressive strength the resulted C/POFA composites. The mixture of cement paste was between water, sand and cement and the standard ratio for mixing cement and sand is 1:2, respectively with 0.4 ratio of water addition from the overall mixture total weight. In this experiment, the cement been mixed with POFA into fixed ratio of total weight 1:2, which is 1 portion (cement + POFA): 2 portions (sand). Four types of composition of cement and POFA which were C/POFA 0 (100/0wt.% of cement/POFA), C/POFA 1 (90/10wt.% of cement/POFA), C/POFA 2 (80/20wt.% of cement/POFA), C/POFA 3 (70/30wt.% of cement/POFA) been studied. The study on the impact strength and compressive strength of each mixture were by using pendulum impact testing machine and universal testing machine (UTM), respectively. In

addition the compression test was performing in order to determine the strain, stress, and deformation of the resulted C/POFA composites. Also the hardness test would be evaluated to the specimen in order to analyse the surface strength due to correlation in between of surface hardness test and impact test. Other than that, the physical testing performs that was water absorption test in order to calculate the water absorption capacity for cement paste composite specimen will be performed in-house using the simple set-up of water bath. In addition, the other physical test been perform that was density test. The density of specimens had been measure using densimeter machine. After that, this specimen will be analysing using the scanning electron microscope (SEM) to determine the microstructural behaviour of cement paste mixture with POFA addition.

1.5 Importance of Study

The important of this study was as it would contribute to the greener and preserved environment and building construction by using natural waste that converted into something useful and beneficial. Also it could contribute to the future research development in the idea of combining pozzalonic based cement material with natural waste of plants origin. The significant of this study is to reduce the use of cement in concrete formulation and to support nowadays situation towards having sustainable and green environment and make use of natural waste (palm oil fuel ash) that might be a new finding or solution to reduce the use of cement in construction. This study on cement based composite would leads into finding of the best mixture of C/POFA composites material that able were to withstand with unexpected extreme load or blast load and this will be very useful in the civil and structure application.

1.6 Research Planning

This study been conducted in one year period with two semesters. The following Gantt chart had summarized the overall milestone and target related with this research.

No	Tasks	Semester 1						Semester 2					
		Month											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Conduct preliminary research (scope out the topic)												
2	Decide your research topic												
3	Literature Review -Search out journal sources -Evaluate all sources in the review												
4	Methodology -Select Methods -Reflect on the effectiveness of the method												
5	Submit/present your research proposal for approval												
6	Finalise your topic & methodology												
7	Conduct research -Collect Data -Short test run on methods -Ensure data is fully collected and secured												
8	Analysis/data processing -Investigate data -Support stories with data, evidence, graphs etc -check the clarity and support of the data stories												
9	Writing up												
10	Review and Improve writing												
11	Submission												

Figure 1.1: The Gantt chart on Research Planning