# PROPERTIES OF CEMENT SAND BRICK CONTAINING GROUND PALM OIL FUEL ASH (POFA) AS PARTIAL SAND REPLACEMENT

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Thesis submitted in fulfillment of the requirements
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## ABSTRAK

Bata campuran simen dan pasir adalah sejenis bata dibuat daripada campuran simen dan pasir. Disebabkan oleh pertumbuhan industri pembinaan di Malaysia, permintaan terhadap bahan binaan seperti pasir telah meningkat. penggunaan pasir yang tidak terkawal akan membawa kepada peningkatan aktiviti perlombongan pasir sungai yang boleh menyebabkan ketidakseimbangan ekologi seperti kemusnahan flora dan fauna, hakisan tebing sungai dan pencemaran air. Abu bahan bakar kelapa sawit (POFA) adalah sisa pepejal sekam kelapa sawit terhasil dari pembakaran semasa proses minyak sawit. Kebiasaanya abu ini dibuang di tapak pelupusan atau kilang-kilang. Dengan menggantikan pasir dengan POFA, perlombongan pasir dan masalah pelupusan sampah dapat dikurangkan serta harga bata campuran simen dikurangkan. Kajian ini bertujuan untuk mengkaji kesan POFA kisar sebagai pengganti separa pasir dan sifat-sifat bata campuran simen pasir. Bidang kajian juga meliputi parameter penting termasuk kekuatan mampatan, kekuatan lenturan, dan penyerapan air dalam menentukan sifat-sifat kejuruteraan. Semua spesimen tertakluk kepada pengawetan udara. Ujian kekuatan mampatan dan lenturan akan dijalankan pada 7, 14, 28 dan 60 hari. Ujian penyerapan air adalah 28 hari selepas bata menjalani proses pengawetan. Berdasarkan keputusan, kekuatan mampatan dan lenturan bata mempamerkan trend yang sama. Ia menunjukkan bahawa bata campuran simen dan pasir yang mengandungi 15% daripada POFA penggantian memberikan hasil yang terbaik dari segi kekuatan mampatan dan kekuatan lenturan. Kekuatan mula meningkat pada 5% penggantian POFA sehingga ia mencapai kekuatan yang tinggi pada 15%. Kemudian ia mula berkurangan apabila penggantian POFA pada 20%. Simen bata pasir yang mengandungi 15% POFA mempamekan penyerapan air yang paling rendah.

# ABSTRACT

Cement sand brick is a type of brick made from a mixture of cement and sand. Due to growth of construction industry in Malaysia, demand toward construction material such as sand will increase. Uncontrollable usage of sand will lead to increase in river sand mining activity that can cause ecological imbalance such as destruction of flora and fauna, river bank erosion and water pollution. Palm Oil Fuel Ash (POFA) is a solid waste from burning palm oil husk and palm oil shell in the boiler of palm oil mill that is usually dumped at landfill. By replacing sand with POFA, sand mining and waste disposal problems can be reduced as well as economical cement sand brick can be produce. This research aims to investigate the effect of ground POFA as partial sand replacement on the properties of cement sand brick. The field of studies also covers important parameters including compressive strength, flexural strength, and water absorption in determining the engineering properties. All the specimen were subjected to air curing. The compressive and flexural strength tests have been conducted on 7, 14, 28 and 60 days. Water absorption were conducted at the age 28 days. Based on result, the compressive and flexural strength of the brick exhibit the same trend. Finding shows that cement sand brick containing 15% of ground POFA replacement give the best results in terms of highest compressive strength and flexural strength. The strength started to increase strength at 5% of POFA replacement until it achieve highest strength at 15%. Then it start to decrease when POFA replacement at 20%. Cement sand brick containing 15% POFA exhibit the lowest water absorption

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of study

A brick is one of the building component used to produce walls, pavements and other materials in masonry construction. Brick is a material that lasts an incredibly long time and practically it no need to maintenance. Generally, the term of brick mention to a unit composed of clay, but now used to represent any rectangular units laid in mortar. A brick can be composed of clay-bearing soil, sand, and lime, or concrete materials. Bricks are manufacture in various classes, types, materials, and sizes which is different with other region and time period, and they are produced in large quantities. Cement sand brick or concrete masonry unit (CMU) is a concrete block that made from cement and aggregate which are generally from sand.

Palm Oil Fuel Ash or POFA is a waste materials that been produce from burning palm oil husk and palm oil shell in the boiler of palm oil mill. POFA is categorized as a mineral admixture. POFA is agricultural by-products which possess pozzolanic properties due to its chemical composition which is high in silica. According to ASTM C 618 pozzolanic materials can be interpret as siliceous or siliceous and aluminous materials which on themselves possess little or no cementitious value but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compound possessing cementitious properties. Since Malaysia is the one of the country that produce palm oil, there are a lot of POFA that have been produce each year. Malaysia facing problems in disposing palm oil fuel ash, a by-product of palm oil mill since many years ago. To counter this problem, the researcher use POFA and other waste material to add into the brick as a partial sand replacement to the mixes to minimize the uses of natural aggregate.

## 1.2 Problem statement

Sand is a key ingredient in the construction industry, especially those involving concrete and road construction. Sand is also widely used for the work of land reclamation and the construction of artificial islands. Sand mining is the removal of sand from their natural configuration, mainly through an open pit. However, sand is also mined from beaches, inland dunes and dredged from ocean beds and river beds. The other reason of sand mining is to extract the minerals such as rutile, ilmenite and zircon, which contain useful component for the industry titanium and zirconium. These minerals typically occur combined with ordinary sand which is dug up. The valuable minerals being separated in water by their different densities and the remaining ordinary sand re-deposited.

However, in recent years several studies have established that human uses of sandy beaches causes significant damages to those ecosystems (Noriega & Schlacher, 2012). Sand mining contribute to impact the river bank erosion, and also cause the destruction of ecosystems of aquatic life. The sand mining also causes turbidity in the water, where it is harmful for the organisms that need sunlight. It also effect the flow of the river where the river will become deeper and swift. People who rely to river water will become worse because the water quality at downstream will be decrease and watersheds resources will be contaminated. Plentiful publications have been write with respect to these effects, and the upcoming footstep to do is to minimize, deter or fixing these environmental problem, as a mitigating measures (Pielou, 1966).

Since Malaysia is one of the world's largest exporter of palm oil. Every year, a lot of palm oil being produce. In 2007, there are around 3 million tons of POFA was produced in Malaysia and 100,000 tons of POFA is produced annually in Thailand. This value is likely to getting rise due to the increment plantation of palm oil trees (Navid Ranjbar, 2014). POFA is waste material that contribute to the environmental pollution. Therefore, to reduce the disposal of POFA thus reducing the use of natural aggregate this product innovation ideas was come out. This also due to the emerged from the government's intention to progressively move forward to the application of green technology and businesses manage waste efficiently palm oil industry.

### 1.3 Objective

The objective of study are :

I. To investigate the effect of POFA as partial sand replacement on compressive strength of cement sand brick.
II. To investigate the effect of POFA as partial sand replacement on flexural strength of cement sand brick.
III. To investigate the effect of POFA as partial sand replacement on water absorption of cement sand brick.

### 1.4 Scope of study

The research is to to incorporate ground Palm Oil Fuel Ash in the production of cement sand brick. Generally, this research purpose is to determine the mechanical properties of cement sand brick containing ground POFA. There are six mixes that being used. One of the mix that have been used is 100% sand as a control mix. For the other mixes, the percentage of POFA used as partial cement replacement is limited 5%, 10%, 15%, 20%, and 25%, only. All the sample were cured using air curing. The compressive strength test and flexural strength test were conducted at the age of 7, 14, 28 and 60 days. The test of water absorption was conducted at age 28 days.

### 1.5 Significance of study

In order to solving problem on how to minimize the Palm Oil Fuel Ash wastage is by replace partially quantity of cement sand brick. Using POFA in making cement sand brick will reduce the pollution because we can minimize the disposal of palm waste materials. At the same time, it will decrease the sand mining activity and also can reduce dependency on uses of natural resources. Besides, by using this POFA in brick making industry it will be advantage for the industry to convert the dispose materials into the construction field. It is because they no need to pay to dispose the waste materials to the landfill and at the same time it can reduce the cost of disposal. By doing this, we can sustain our environment without the pollution. The other waste material can be recycled and produce new product. The incorporation of oil palm industry in cement sand brick is good because it will gives benefit to our construction industry. Besides, the government expectations to make Malaysia towards the green technology can be achieve.

## 1.6 Layout of thesis

Overall there are 5 chapter will be in this thesis where the chapter 1 is an introduction. It will explain about the introduction of this research and it contain various sub-chapter. The first sub chapter explain about the background of study and problem statement in this research. This chapter also point out about the objective and scope of study to describe the purpose study in this research.

Chapter two will elaborates about the issue of sand mining problems in Malaysia. Besides that, explaining about POFA and its properties, statistic of POFA disposal in. In addition, this chapter also contains information about cement sand brick more clearly. Chapter two ended with the environmental friendly of cement sand brick that made up partially from POFA.

Chapter three is about methodology of this research. It started with the introduction then follow by flowchart of this research. Besides, it will elaborate on preparation of material of the POFA and then followed by preparation of making cement sand brick. The manufacture of this brick according to cement sand brick mix design are also discusses. Furthermore, type of materials and mix proportion are also contain in this chapter. This chapter is ended with discussion on the testing method adopted in order to investigate the performance of the brick due to its compressive strength, flexural strength and water absorption.

In chapter four it discuss about the experimental result that obtain when conduct the experiment. This chapter also will explain about mechanical properties of the brick such as compressive strength, flexural strength and moisture absorption after subjected to several testing. Finally, chapter five presents the conclusion and recommendations for future study.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

In this chapter will discuss various type of topics and reading material which can help to study the properties of cement sand brick containing ground POFA as partial sand replacement. The topics discussed generally on sand mining activity in Malaysia and the effect of sand mining to the environment. Besides, this section also review about the POFA and the properties of POFA described in more detail. In addition, this chapter describes about the brick, type of brick and its properties. For the last subtopic it will explain about the waste materials in Malaysia including their management and the challenges.

## 2.2 Aggregate

Aggregate is one of the main element used in construction industry. Aggregate can be classified as two different type which is coarse and fine aggregate. The aggregate can be classified as coarse aggregate when the size are more than 4.75mm while fine aggregate is less than 4.75mm. In brick making, fine aggregate or sand occupy between 60% - 80% in the mix. In this research, only fine aggregate will be discuss.

### 2.2.1 Sand mining

For centuries, human have been enjoy use the natural benefits provided by river without understanding much on how the river ecosystem functions and maintain its vitality (Naiman et al, 1998). In figure 2.1 about 35,577,567 tonnes of sand and gravel have been mining in year 2013 (Jabatan Mineral dan Geosains Malaysia, 2013) Sand mining is the removal of sand from their natural configuration such as river. Sand can be used for all types of projects like land reclamations, the construction of artificial islands and coastline stabilization. There are two types of sources that sand is mined from, terrestrial and marine deposits. The most common terrestrial sources are river channel deposits, floodplain alluvial deposits and residual soil deposits which is the marine sources are the shore and offshore deposits (Phua, 2004).In Malaysia, the main source of sand is from in river mining. This type of sand mining is shown in figure 2.2. This type of mining is a commonly used because mining locations are near the "market" or along a transportation route, which can lower the transportation costs (MNR, 2009). These projects have good effects on economy and social, but sand mining also contribute to the environmental problems. This problem occur when the rate of extraction of sand, gravel and other materials exceeds the rate at which natural processes generate these materials. Therefore, this problem need to fix in order to protect our environment for next generation.

| Non-Metallic Mineral | Aggregates | Barytes | Clays & Earth mat. | Feldspar | Kaolin | Limestone | Mica | Sand & Gravel |
|---|---|---|---|---|---|---|---|---|
| Johor | 41,747,492 | - | 6,176,076 | - | 28,651 | - | - | 8,398,633 |
| Kedah | 10,073,474.39 | - | 3,188,546 | - | - | 498,862 | - | 1,464,081 |
| Kelantan | 2,749,522 | 500 | 197,642 | 277,061 | - | 226,101 | - | 174,317 |
| Melaka | 2,157,513 | - | 737,842 | - | - | - | - | 279,149 |
| N.Sembilan | 11,336,400 | - | 1,546,970 | 37,338 | - | 2,475,636 | - | 1,644,474 |
| Pahang | 3,859,055 | - | 1,430,415 | - | 58,850 | 310,794 | - | 4,793,222 |
| Perak | 24,606,628 | - | 6,388,740 | - | 205,979 | 15,781,066 | 4,363 | 5,708,100 |
| Perlis | 2,915,840.22 | - | 1,739,273 | - | - | 656,871 | - | - |
| P.Pinang | 6,775,639 | - | 34,420 | - | - | - | - | - |
| Selangor/KL | 25,522,229 | - | 2,785,982 | - | - | 2,106,581 | - | 8,644,780 |
| Terengganu | 5,580,557 | - | 3,206,454 | - | - | - | - | 811,877 |
| Sabah | 5,262,553 | - | 561,061 | - | - | 341,000 | - | 638,436 |
| Sarawak | 10,586,528 | - | 1,837,484 | - | - | 5,095,135 | - | 3,020,499 |
| **Total/tonnes** | 153,173,431 | 500 | 29,830,904 | 314,399 | 293,480 | 27,492,046 | 4,363 | 35,577,567 |

Figure 2.1 Mineral extraction in year 2013

Source : Jabatan Mineral dan Geosains Malaysia

Figure 2.2 Sand mining located at Johor
Source : (Roket Kini, 2015)

### 2.2.2 The Effects of Sand Mining

In recent years, the sand mining activities in Malaysian rivers have created several environmental problems, such as the deterioration of river water quality, bank erosion, river bed degradation and buffer zone encroachment. All of these are results of excessive sand extraction along the river. Heavy rainfall and soil erosion have resulted in severe sedimentation of Malaysian rivers. Rapid developments, such as land clearing for urban housing, logging and agriculture, have caused erosion and sedimentation in the rivers (Tan and Rohasliney, 2013). River sand mining causes the destruction of aquatic habitats by bed degradation, lower water levels and channel degradation (Lawal, 2011).

The processes associated with channel degradation are large scale removal of river sediments, digging below the existing riverbed and changing the channel bed form and shape (State Policy on River Sand and Stone, 2001). All of these cause soil erosion and sedimentation in the water bodies, which reduce water quality. The physical disturbance of the sediment while dredging the sand affects the suspended solids and increases the turbidity of the water. Turbidity occurs when there are particles in the water that absorb light and cause backscattering (Supriharyono, 2004). The turbidity degraded water quality and the reduced light penetration within the river affect the photosynthesis rates and the primary production rates of the river. Turbidity also affects the fish populations in the river. Siltation, which causes high turbidity in the water make it becomes clogged in the fishes' gills (Phua, 2004). Clogging can lead to infections and the death of the fishes. High turbidity levels also reduce the visibility of certain fish that rely on vision to feed.

#### 2.2.2.1 Destruction of flora and fauna

The most important effects of instream sand mining on aquatic habitats are bed degradation and sedimentation, which can have substantial negative effects on aquatic life. These have caused major habitat disruptions that favoured some species over others and caused overall declines in biological diversity and productivity. Figure 2.3 show the effect of sand mining in destruction of flora and fauna. In most streams and rivers, habitat quality is strongly linked to the stability of channel bed and banks. Unstable stream channels are inhospitable to most aquatic species. The stability of sand-bed and gravel-bed streams depends on a delicate balance between streamflow, sediment supplied from the watershed, and channel form. Mining-induced changes in sediment supply and channel form disrupt channel and habitat development processes. Furthermore, movement of unstable substrates results in downstream sedimentation of habitats. The affected distance depends on the intensity of mining, particles sizes, stream flows, and channel morphology. The complete removal of vegetation and destruction of the soil profile destroys habitat both above and below the ground as well as within the aquatic ecosystem, resulting in the reduction in fauna populations.


Figure 2.3 Destruction flora and fauna
Source : (Sinar Harian, 2015)

### 2.2.2.2 Bank erosion

Sand-and-gravel mining in stream channels can damage public and private property. Channel incision caused by gravel mining can undermine bridge piers and expose buried pipelines and other infrastructure. The excavation of a mining pit in the active channel lowers the stream bed, creating a nick point that locally steepens channel slope and increases flow energy (Kondolf, 1998). Instream mining can result in channel instability through the direct disruption of pre-existing channel geometry or through the effects of incision and related undercutting of banks (Collins & Dunne, 1989). Mining aggravates widespread instability because the discontinuity in the sediment supply-transport balance tends to migrate upstream as the river bed is eroded to make up for the supply deficiency (Knighton, 1984). Thus sand mining from a relatively confined area triggers erosion of bed and banks which means it may affect the stability of the structures. Figure 2.4 show bank erosion effect due to sand mining activity.


Figure 2.4 Bank erosion
Source : (Ako, 2014)

#### 2.2.2.3 Water pollution

Figure 2.5 show one of the river that have been polluted. During the processes of mining, the sand particles are selectively removed using specially fabricated porous scoopers. This process not only increases the turbidity level, but also enhances the silt and clay concentrations in the overlying waters. The turbidity introduced by mining of sand is a havoc to the instream plants and animals in the river ecosystem. The coating of fine materials over leaves adversely affects the photosynthesis of aquatic macrophytes and benthic algae. For filter feeders in the water column as well as on the substrate, the solids may interfere with the filtration process. Some solids clog on to gills of fishes and invertebrates leading to asphyxiation. Deposition of silt on river bed can smother diatoms, benthic algae, macro invertebrates and fish eggs (Lake et al, 1999).

Figure 2.5 Illustration of water pollution
Source : (Mekong Eye, 2017)

### 2.3 Industrial by-product as replacement material

Industrial activity produce abundance of by-product materials such as rice husk ash (RHA), fly ash, ground granulated blast furnace slag (GGBS), metakaolin and etcetera. To reduce the dumping of this waste to the landfill the researcher take this opportunity to use this waste in concrete and brick to replace partially of the cement and sand content. This is known as supplementary cementing material. As all of this by-product contain reactive silicon dioxide which can contribute in the pozzolanic reaction and affect the development of the late stage of curing.

#### 2.3.1 Rice Husk Ash (RHA)

Rice Husk Ash (RHA) is an agricultural waste material that exist abundantly and available in the rice-producing country. It is an agricultural waste product after it had been burned. The RHA is burn and ground into fine particles. Figure 2.6 illustrate rice husk ash where it normally burning at 500°C to 700°C and it result in amorphous material. It had been proved that RHA is a good pozzolan and it can be used as a replacement with cement in concrete (Obilade, 2014). The ash formed during open-field burning or uncontrolled combustion in furnaces which generally contains a large proportion of less reactive silica minerals and must be ground to a very fine particle size in order to contribute in pozzolanic activity. 0% to 20% is the optimum of replacement of RHA with cement in term of mass. According to (Dabai et al, 2009), a chemical analysis had been carried out on the RHA and it resulted that RHA consists of high content of silicon dioxide, 68.12%, aluminium oxide, 1.06%, calcium oxide, 1.01% and iron oxide, 0.78%. Those chemical compounds take part in the pozzolanic activity in cementitious materials. A highly pozzolanic ash can produce by controlled combustion when silica is retained in non-crystalline form and a cellular microstructure. The compressive strength of the concrete with replacement of 10% RHA replacement is decrease for 11% as compared to the control sample. This showed that the strength decrease with the increase in the replacement of RHA (Dabai et al, 2009). Since the sewage sludge is similar to RHA as both of them contain silicon dioxide, aluminium oxide and calcium oxide which can be used in pozzolanic reaction to increase the strength of the cement based material.

Figure 2.6 Example of raw rice husk ash
Source : (Della et al, 2002)

### 2.3.2 Fly Ash

Fly ash can also be known as Pulverised Fuel Ash (PFA). It is a by-product from the burning of powdered coal in electric generating power plants. Fly ash is collected in the dust-collection systems (electrostatic or mechanical precipitators) that remove particles from the exhaust gases. It is one of the most common materials to be used to replace the cement in construction field. Figure 2.7 illustrate fly ash that have been

produce at the factory. The research by (Fanghui et al, 2015) stated that the ground fly ash can replace the cement up to 20% to 40%. Not only that, once the fly ash is added into the cement based material, it can actually reduce the emission of $CO_2$ during the hydration process of cement. Retardation of hydration process of cement at early stage and acceleration of hydration process in later stage happened during the replacement of cement with fly ash (Narmluk & Nawa, 2011). As long as the fly ash used in the replacement of cement, it can surely reduce the waste management problem and indirectly save up the cost and energy. According to Christy & Tensing (2010), the replacement of 10% of fly ash has higher compressive strength as compared to control mix at 28 days of curing. There are similarities between fly ash and sewage sludge as both of them will delay the hydration process when they had been added into the cement based material.

Figure 2.7 Pulverised Fly Ash
Source : (Shepard)

### 2.3.3 Ground Granulated Blast furnace Slag (GGBS)

Ground Granulated Blast furnace Slag (GGBS) as shown in figure 2.8 is a non-metallic product that consisted of silicates and aluminates of the calcium base. As GGBS is pozzolanic and also cementitious so that it is very suitable to be used in the replacement of the cement in concrete. The GGBS can improves the workability and make the mix more mobile but cohesive. The finer GGBS reduces the bleeding of the concrete and it will retard the setting time by 30 to 60 minutes. The replacement of GGBS can be from 25% to 70% with cement in the cement based material. The blended Portland GGBS cement contains more silica and less lime than Ordinary Portland Cement alone, resulting higher C-S-H gel, thus the concrete is denser and it is more durable. Same goes with sewage sludge, it will have slow early strength development but higher later strength.

Figure 2.8 Ground Granulated Blastfurnace Slag (GGBS)
Source : (SK Enterprise)

## 2.4 Palm oil fuel ash

Malaysia produces bountiful amount of waste namely, palm oil fuel ash and oil palm shell from the palm oil mill. Over 6.89 million tonnes of oil palm shell (Chong, 2013) and 4 million tonnes of palm oil fuel ash are generated annually in Malaysia (Mohamed, 2005). Palm oil fuel ash is a waste materials produced in palm oil mill. To produce POFA, Palm oil is extracted from the palm oil fruit as show in figure 2.9. Then both palm oil husk and palm oil shell are burned as fuel in the boiler of palm oil mill. Normally, after combustion completed, about 5% palm oil fuel ash by weight of solid wastes is produced (Sata et al, 2004). The colour of the POFA that produce will varies in from whitish grey to darker shade it depend on the carbon content in it. In other words, the operating system in palm oil factory will affect the physical characteristic of POFA. In practice, POFA produced in Malaysian palm oil mill is dumped as waste without any profitable return (Sumadi & Hussin, 1995). POFA is considered as a nuisance to the environment and disposed without being put for any other use as compared to other type of palm oil by-product. Since Malaysia is continuous to increase production of palm oil, therefore more ashes will be produced and failure to find any solution in making use of this by-product will create severe environmental problems.

Figure 2.9 Palm oil fruit
Source : (Riausky, 2015)

Through studies conducted earlier, the POFA as show in figure 2.10 is found pozzolanic material. A pozzolana (Neville, 2005) is a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing. POFA containing high pozzolanic material which is not only can replace part of the cement, but also can improve the strength and durability of concrete. POFA use in concrete gives good results in optimal mixture compared to normal concrete.

Figure 2.10 Illustration of POFA
Source : (Kamaluddin, 2016)

### 2.4.1 Chemical properties of POFA

Different types of agricultural wastes have separate physical and chemical properties, which can be used in concrete with proper selection. Chemical analysis showed that the POFA generally meet pozzolan properties and are classified as Class C pozzolan as described in ASTM C618-92a (Awal & hussin, 1997). This pozzolanic material is grouped in between Class C and Class F as specified in ASTMC618-92a (Awal & Hussin, 1997). POFA is moderately rich in silica content meanwhile lime content is very low as compared to OPC (Awal & Hussin, 1997). However, the chemical composition of POFA can be varied due to operating system in palm oil mill. The table below show the comparison of chemical properties of OPC and POFA.

Based on research of Characterization of Palm Oil Fuel Ash (POFA) from Different Mill by Dominic Galau in table 2.1, the major chemical composition of POFA is $SiO_2$, about more than 50%. It prove that POFA properties is high in Silica content where it is most important chemical content for POFA or other replacement material. Silica content can improve the strength of POFA concrete. Strength of concrete generally increased with the increasing of silica content in concrete (Lawrence, 1998). While the sulphur trioxide, $SO_3$ is one of the most unwanted chemical content in chemical composition for every cement replacement material. Strength test showed that, with increasing silica ratio strength was generally increased and reduced with increasing of $SO_3$ (Lawrence, 1998).

Besides, table 2.2 shown that the comparison chemical composition of Ordinary Portland Cement with POFA. From the result, it display that the composition is almost the same. That why POFA is suitable to be used in cement replacement materials.

Table 2.1 Chemical composition of POFA based on different mills

Source : (Dominic Galau, 2010)

| Chemcal compositions | Mill | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Kota Tinggi | Masai | Alaff | Kluang | Trong | Rantau | Pekan | Carey |
| Silica ($SiO_2$) | 52.50 | 52.30 | 59.60 | 49.20 | 71.20 | 56.70 | 71.20 | 58.30 |
| Ferric Oxide ($Fe_2O_3$) | 5.73 | 6.78 | 8.77 | 5.73 | 7.12 | 11.40 | 10.10 | 9.77 |
| Calcium Oxide (CaO) | 11.30 | 10.80 | 8.06 | 17.50 | 4.37 | 6.81 | 5.68 | 6.72 |
| Magnesium Oxide | 3.55 | 5.43 | 3.90 | 3.53 | 1.95 | 3.31 | 1.31 | 3.69 |
| Sulphur Trioxide | 0.82 | 1.76 | 0.57 | 1.73 | 0.89 | 0.87 | - | 0.96 |
| Potassium Oxide ($K_2O$) | 10.20 | 11.40 | 7.64 | 9.49 | 5.59 | 7.83 | 5.68 | 8.40 |
| Carbon ($CO_2$) | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |

Table 2.2 Comparison chemical composition of Ordinary Portland Cement and POFA

Source : (Awal & Hussin, 2009)

| Tests | OPC | POFA |
|---|---|---|
| **Physical properties** | | |
| Fineness - Sp. surface area($m^2$ /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 ($Al_20_3$) | 5.70 | 11.40 |
| Ferric oxide ($Fe_2O_3$) | 3.00 | 4.70 |
| Silicon dioxide ($SiO_2$) | 20.20 | 43.60 |
| Aluminum oxide ($Al_20_3$) | 5.70 | 11.40 |
| Ferric oxide ($Fe_2O_3$) | 3.00 | 4.70 |
| Silicon dioxide ($SiO_2$) | 20.20 | 43.60 |
| Aluminum oxide ($Al_20_3$) | 5.70 | 11.40 |
| Ferric oxide ($Fe_2O_3$) | 3.00 | 4.70 |

### 2.4.2 Strength and durability of POFA

In bulk, palm oil fuel ash (POFA) is grey in colour that becomes darker with increasing proportions of unburned carbon. The particles have a wide range of sizes but they are relatively spherical. In term of strength, Replacement of POFA in ordinary portland cement lightweight aggregate concrete (OPS LWAC) from 10% to 30% resulted in strength higher than plain OPS LWAC. In strength of OPS LWAC with POFA could be attributed by the filling effect of the fine ash and also the pozzolanic reaction that improves the bond between the hydrated cement matrix and the aggregates.

The research showed that, POFA concrete is weaker at early age, but at later ages the compressive strength is found to be higher than that of OPC concrete (Awal and Hussin, 1998) as shown in figure 2.11**.** In general, specimens consisting POFA exhibit lesser strength at early age but compressive continue to increase as curing age become higher. This is because pozzolana starts reacting somewhat belatedly with the calcium hydroxide produced by clinker hydration and therefore it behaves like an inert diluting agent towards the Portland cement with which it has been mixed (Massaza, 1993).

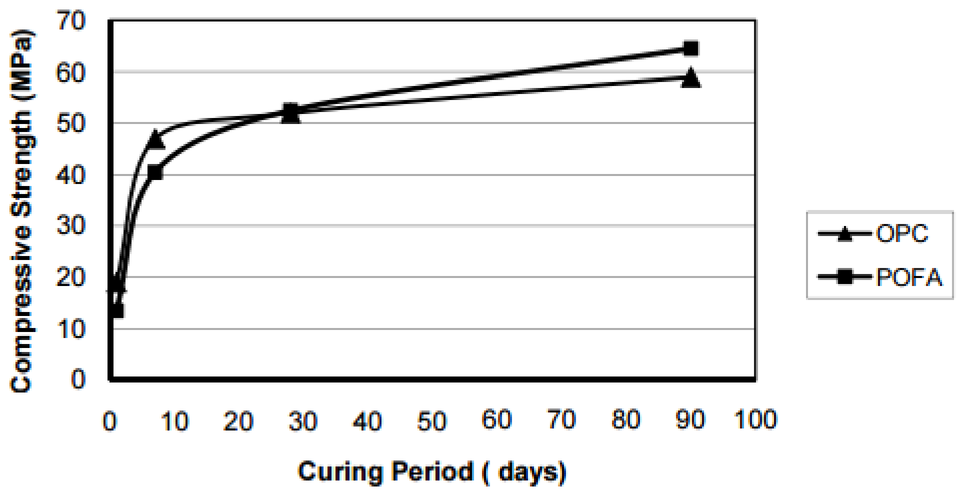


Figure 2.11 Comparison concrete compressive strength of POFA and OPC

Source : (Awal and Hussin, 1997)

It also has been found that POFA could produce a more durable concrete. POFA possess good characteristic towards chemical attack especially sulphate and acid and also other chemical agent when it is used as partial cement replacement in concrete mix Awal

(1997). As an additional benefit Awal & Hussin (1997) also stated that incorporation of POFA as partial cement replacement in concrete result in significant increase in chemical resistance to acidic environment. Moreover, despite the higher alkali content POFA, it has been effective in suppressing expression due alkali-silica reaction.

### 2.4.3 Treatment and grinding process of POFA

The origin size of POFA is about 2.3mm which is larger than cement size. By Tangchirapat, the strength of concrete is influenced by the fineness of POFA and cement. So to improve the concrete properties, the POFA is grinded. (Awal & Hussin, 1996) found that the POFA has low pozzolanic reaction due to its large particle size and porous structure, which could be enhanced by grinding the POFA. Thus, many researchers come with method and procedure to produce high fineness of POFA. In order to achieve better strength of concrete consisting POFA, Awal and Hussin (1996) have been suggested that finer POFA is to be used. By increasing the fineness of POFA would lead to greater strength development than the coarser one. In Figure 2.12, it can be seen that the development in strength with the fineness of ash. And that was due its lower surface area of the particle that affect the pozzolanic activity and hence the strength.

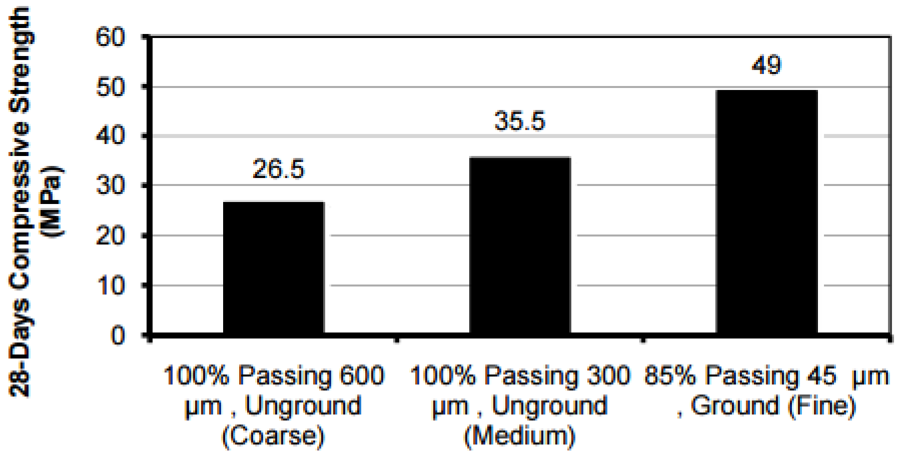


Figure 2.12 Effect of fineness of ash on compressive strength of concrete
Source : (Awal,1998)

Chandara (2010) suggested that the POFA was dried in an oven at 105 ± 5 °C for 24 hours and then sieved through a 300 µm sieve to remove larger particles, fibres and grains that underwent incomplete combustion in the palm oil mill. The POFA was then ground in a laboratory scale ball mill for 10 h to obtain ground POFA and to achieve improved efficiency of the subsequent heat treatment. Recently, (Megat Johari et al, 2012) modified the treatment and grinding process of POFA production through heat treatment in order to remove the excess carbon content and to decrease the median particle size of POFA by about 2.06 µm. Different method from Yusuf, POFA was first milled for 8 hours to reduce its grain sizes and then calcined at 500°C ± 50°C to remove its unburned carbon.

### 2.4.4 Benefits of addition POFA

Due to the environmental issue appear on disposal these agricultural wastes to the environment. The idea of usage POFA in order to minimize the waste material have giving advantage to us to become an environmental friendly country. The utilization of POFA in construction industry has contribute great impact to the environment. The addition of POFA in concrete production is an alternative ways for the disposal problem of POFA.

Among the benefits of using POFA in construction industry is reduce the cost of concrete production due to minimization of cement content. With high fineness, POFA can be used as a cement replacement to produce high-strength concrete, it also reduces the water permeability of concrete, shows smaller degree of expansion and loss in compressive strength with compare to concrete made with OPC type I cement (Tangchirapat, 2009). POFA also have a potential in suppressing expansion due to alkali-silica reaction. Added POFA in producing concrete will create concrete with good resistance against sulphate attack (Mirasa, 2015). In addition, POFA can be used as pozzolans to replace part of Portland cement in making mortar with relatively high strength and good resistance to chloride penetration (Chindaprasirt, S. Rukzon, V. Sirivivatnanon, 2008).

## 2.5 Brick

A brick is a walling unit whose form may be generally defined as a rectangular prism of a size that can be handled conveniently with one hand (Lynch, 1994). Bricks are widely used since in the past centuries due to its values and advantages. Brick is a popular medium for constructing buildings. It consist of high mass materials with good compressive strength formed into units that can be lifted and handled by a single worker. Cement sand brick is a type of brick made from a mixture of cement, sand and water. The typical size for the brick is 100mm X 65mm X 215mm. Meanwhile, the average weight of this type of brick is 2.6 kg with 7 N/mm2 as its compressive strength.

In the market, there are several types of bricks that can be found and being used in the construction industry. The classification of the bricks depended on the materials and method used in making those different types of bricks. The commonly used bricks types are clay bricks, sand-lime bricks and concrete bricks. These types of bricks had been standardized for its usage.

### 2.5.1 Clay Bricks

Clay brick as shown in figure 2.13 is most commonly used brick in today's construction. The main material used in making this type of brick is clay. In Malaysia, the usage of clay brick in construction has to refer to BS 3921: 1985 (Specification for Clay Brick). By referring to BS 3921: 1985, the work size of clay brick had been set to 215 mm x 102.5 mm x 65 mm while the coordination size of clay brick had been set to

225 mm x 112.5 mm x 75 mm. Work size means the actual size of the bricks that should conform within specified permissible deviation while coordinating size means the size of a coordinating space allocated to a brick including allowances for joints and tolerances. Table 2.1 which is extracted from BS 3921: 1985 shows the size of the clay brick. Clay brick can further classified into three categories; common bricks, facing bricks and engineering bricks

The properties of the bricks depended on the materials and method used to produce the bricks. Several properties that majorly used to distinct the quality of bricks are compressive strength, water absorption and fire resistance. Compressive strength of clay bricks is one of the factors that determine the properties of the end products. Clay bricks are high in compressive strength but relatively weak in tension. Clay bricks can vary in strength from about 7 N/mm2 to well over 100 N/mm2. The strength of clay bricks also varies with the bricks' porosity. For low rise buildings, bricks of 5.2 N/mm2 should be sufficient (Hendry,2003). As for the high rise building, engineering bricks or those with higher compressive strength are used.

Figure 2.13 Clay brick

Source : (India mart, n.d.)

### 2.5.2 Sand-lime

Figure 2.14 illustrate an example of bricks Sand-lime bricks or also known as calcium silicate bricks are made using mixture of lime and sand with the proportion of 1:8 added with water. Pressure and heat are applied for the sand and lime to mix together and react chemically to form the bricks. After that, the bricks are demoulded and cooled. They are then put into the autoclave machine and applied with heat and pressure for further hardening. The compressive strength of the bricks is between 7 $N/mm^2$ to 50 $N/mm^2$. The colour of the sand-lime bricks is commonly light grey. BS187 included the details of the minimum specifications for the production of sand-lime bricks.

Figure 2.14 Sand lime brick
Source : Google image

### 2.5.3 Concrete Bricks

Production of concrete bricks in figure 2.15 is similar to the sand-lime bricks with sand and Ordinary Portland Cement as the mixture materials. The concrete is hardened by conventional water curing process or special compression method. BS 1180 stated the minimum requirements for the bricks and its classification. Similar to the clay bricks, concrete bricks also available in three categories: common bricks, engineering bricks and facing bricks.

Figure 2.15 Cement sand brick
Source : Google image

### 2.5.4 Green Brick

As of the year of 2008, 23,000 tonnes of waste is produced each day in Malaysia, with less than 5% of the waste is being recycled. In Selangor alone, waste generated in 1997 was over 3000t/day and the amount of waste is expected to rise up to 5700t/day in the year 2017 (Yachio Engineering, 2000). The latest statistics indicated that Malaysians produced 33,000 tonnes of solid waste a year, and of the total, only 10.5% had been recycled into value-added products. Statistic show that the amount of waste material dispose keep arise, hence a solution need to be take in order to minimize of this waste. Therefore, a green brick have been introduce to overcome this problem. Green brick is brick that made up from waste materials where the raw partially replace by the waste. There are various type of brick that made up of waste materials from industry such as fly ash, sludge, quarry dust and etc. used of green brick reduced effect on human health and the environment when compared with usual brick. This brick also can assist in reduction of the energy used in the building during operation and maintenance.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

An experiments have been conducted to determine the effects of adding POFA as a partial sand replacement material in high strength cement sand brick. In this chapter materials and testing method will be explain specifically. This will includes all the material required and casting of the specimen. All the specimen needed to be tested in order to analyse and present the data. Several testing have been conducted to study the effect of adding POFA as partial sand replacement toward cement sand brick. All the testing were conducted in accordance to ASTM standard.

## 3.2 Flowchart of experimental work

The flow of experimental process for an evaluation of the testing methods is outlined in Figure 3.1.

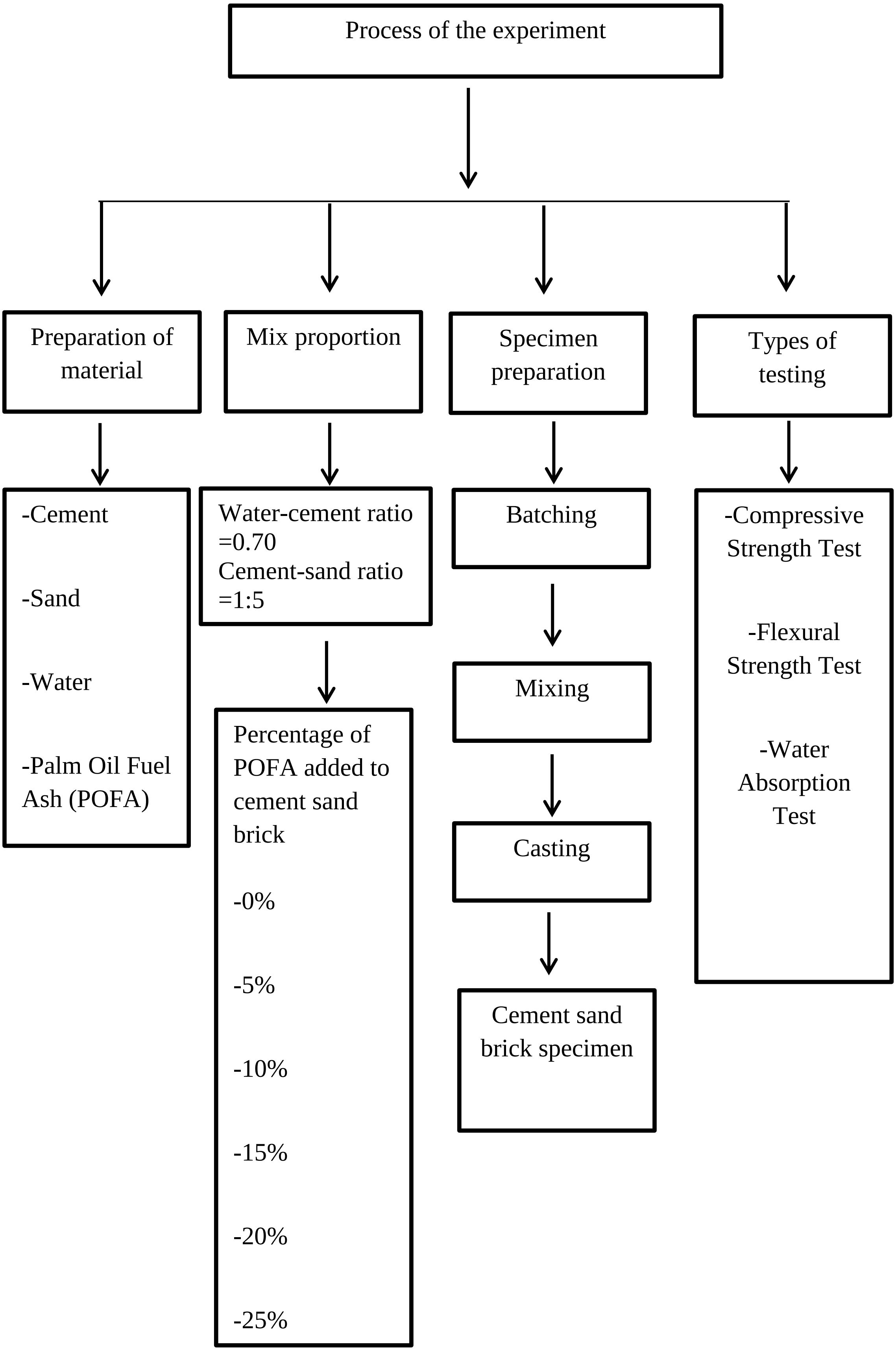


Figure 3.1 Flowchart of experimental work

### 3.3 Materials

In this study, the materials that will be used for making cement sand bricks are cement, sand, water and ground Palm Oil Fuel Ash (POFA).

#### 3.3.1 Cement

Cement is a powdery substance made with calcined lime and clay. Cement is a substance used as a binding agent that can hardens and bind other materials together. Cement are used as a component in the production of mortar in masonry and concrete, which is a combination of cement and aggregate to form a strong building material. In bricks production, the cement is assisted by water to bind sand in the mould. Meanwhile, for this experiment, the cement will bind together with POFA and sand with the presence of water. Cement that will be used in this experiment is Ordinary Portland Cement brand Orang Kuat in figure 3.2. This type of cement follows the Malaysian Standard MS 522: Part 1: 2007 for Portland cement specification.


Figure 3.2 Orang kuat Ordinary Portland Cement

### 3.3.2 Sand

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. Sand is classify by size which is finer than gravel and coarser than silt. Sand is also refer to a textural class of soil or soil type. Soil are consist more than 85% sand-sized particles by mass. For the making of cement sand brick, sand in figure 3.3 is added along with other materials which are cement and water in the mould to shape the brick and complete the mixture.

Figure 3.3 Air dry river sand

### 3.3.3 Water

Water is one of the element that has most important part in construction industry. The water is required for preparation of mortar, mixing of cement concrete and for curing work during construction work. The quality and quantity of water has much effect on the strength of brick, mortar and cement concrete in construction work. The water used for mixing and curing should be clean and free from injurious quantities of alkalis, acid, oils, salt, sugar, organic materials, vegetable growth and other substances that may be deleterious to bricks, stone, concrete or steel. Potable water as illustrate in figure 3.4 is generally considered satisfactory for mixing. The pH value of water should be in neutral phase which is in range 6.5 to 8.5. Water used need to be clean and free from impurities that can affect the specimen result. The amount of water used in this experiment depends on the mix design.

Figure 3.4 Tap water

### 3.3.4 Palm Oil Fuel Ash (POFA)

Palm Oil Fuel Ash is a by-product from Palm oil industry that was collected. The composition of POFA is high in silica content which is almost similar to the sand. Sand quantity will be replaced partially with POFA. Then, cement sand brick will be casted with different percentage of POFA and sand in their mixture. POFA that have been used in this experiment is ground POFA. The process of the POFA treatment will be explained detail below in figure 3.5. This POFA have been collected at LKPP Corporation Sdn Bhd located at Ladang Lepar Baru, Gambang Pahang.


Figure 3.5 POFA treatment

#### 3.3.4.1 Processing Ground POFA

Palm oil fuel ash (POFA) was used in this research to replace natural sand inside the brick. POFA was collected from the palm oil mill and then it will be places inside a gunny bag to be transfer to FKASA laboratory. At the laboratory, POFA that were collected need to be cleaned to remove all dirt because raw materials that have been collected was mixed with fibre. After cleaning process was done POFA was left to dry inside the oven at 105±5 °C for 24 hours. After 24 hours, the POFA were sieve by using sieve size 300 μm. Only the amount of POFA that passing the sieve size were used. Next, the POFA that have been sieve will be grind using grinding machine with 5600 rpm. The POFA that have been grind only will be used in this research. All the picture that related to POFA are shown below, starting from obtaining POFA at palm oil mill until finished grinding process, which are from figure 3.6 until figure 3.9.

Figure 3.6 Obtaining palm oil fuel ash at the LKPP Corporation mill.


Figure 3.7 POFA oven dry for 24 hours


Figure 3.8 Sieve POFA

Figure 3.9 POFA was grind

### 3.4 Mix proportion

Mixing process of the brick was done by using standard brick making procedure. The brick was mix by using mechanical mixer. All the specimen were weighted according to the mix design before mixing. All fine palm oil fuel ash (POFA) were used as a partial sand replacement in this research. The amount of replacement were 0%, 5%, 10%, 15%, 20% and 25% by the weight of the sand. A total of 3 mix were used in this experiment. Water-cement ratios of 0.7 is use. Cement-sand ratio that have been used is 1 : 5. Besides that, the size of cement sand brick is 100mm x 65mm x 215mm (WxHxL). The volume of one brick specimen is $1.365 \times 10^{-3}$ $m^3$. The normal weight of a brick was 2.7kg. Table 3.1 shows in detail the mix proportion of the specimen used in this research. Table 3.2 represent the total specimen for each test.

Table 3.1 Mix proportion by weight per volume

| Samples | Cement ($kg/m^3$) | Sand ($kg/m^3$) | POFA (%) | POFA ($kg/m^3$) | Water ($kg/m^3$) |
|---|---|---|---|---|---|
| A | 330 | 1648 | 0 | 0 | 231 |
| B | 330 | 1566 | 5 | 82.4 | |
| C | 330 | 1484 | 10 | 165 | |
| D | 330 | 1401 | 15 | 247 | |
| E | 330 | 1319 | 20 | 330 | |
| F | 330 | 1236 | 25 | 412 | |

Table 3.2 Total specimen for each test

| Type of testing | Percentage replacement (%) | No of sample by curing days | | | | Total samples |
|---|---|---|---|---|---|---|
| | | 7 Days | 14 Days | 28 Days | 60 Days | |
| Compressive strength | 0 | 3 | 3 | 3 | 3 | 72 |
| | 5 | 3 | 3 | 3 | 3 | |
| | 10 | 3 | 3 | 3 | 3 | |
| | 15 | 3 | 3 | 3 | 3 | |
| | 20 | 3 | 3 | 3 | 3 | |
| | 25 | 3 | 3 | 3 | 3 | |
| Flexural strength | 0 | 3 | 3 | 3 | 3 | 72 |
| | 5 | 3 | 3 | 3 | 3 | |
| | 10 | 3 | 3 | 3 | 3 | |
| | 15 | 3 | 3 | 3 | 3 | |
| | 20 | 3 | 3 | 3 | 3 | |
| | 25 | 3 | 3 | 3 | 3 | |
| Water absorption | 0 | - | - | 3 | - | 72 |
| | 5 | - | - | 3 | - | |
| | 10 | - | - | 3 | - | |
| | 15 | - | - | 3 | - | |
| | 20 | - | - | 3 | - | |
| | 25 | - | - | 3 | - | |

### 3.5 Specimen preparation

The preparation of the specimen start by preparing the Groun POFA samples. Next other material such as cement, sand and water was prepared for the process to make cement-sand brick. The flow of the specimen's preparation is shown in Figure 3.10.

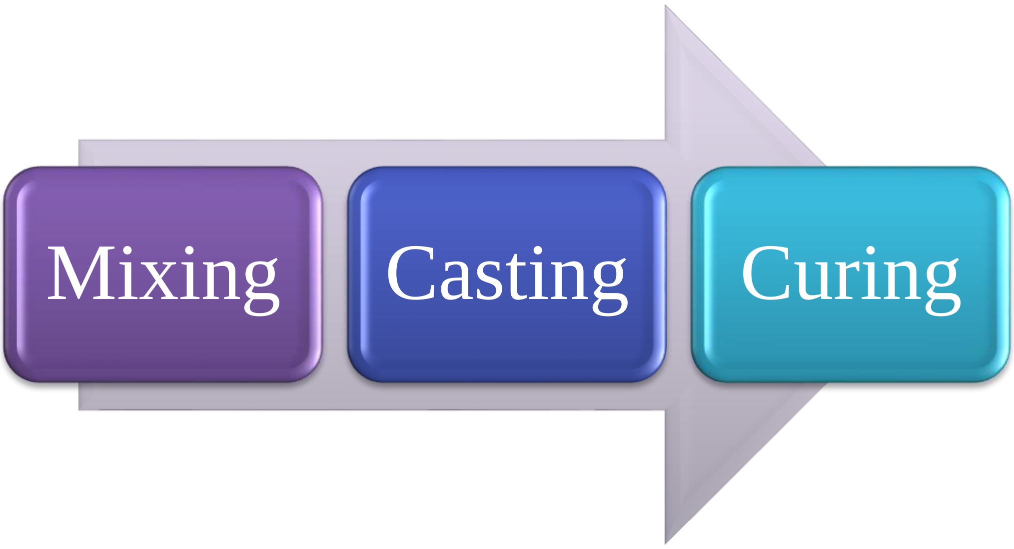


Figure 3.10 Specimen preparation flow

#### 3.5.1 Mixing and casting

For mixing process electric mixer machine was used to ensure all materials were mixed properly. Figure 3.11 show in detail the type of casting machine used. The mix were then being pour into wood mould and compacted manually by hand. The specimen were covered with wet gunny sacks and left for one night. The specimen will be unmould for the next day and the sample was cured using air curing. The mould was built manually by hand. Figure 3.12 shows the actual picture of the mould used. The surface of the mould need to be oiled to make easier when removing it and to avoid the wood absorb the water from the specimen. It is important to check the mould condition before mixing because any damage to the mould can affect the testing result of brick. Figure 3.13 show the specimen have been unmould and ready for subject to curing in figure 3.14.


Figure 3.11 Mixer machine

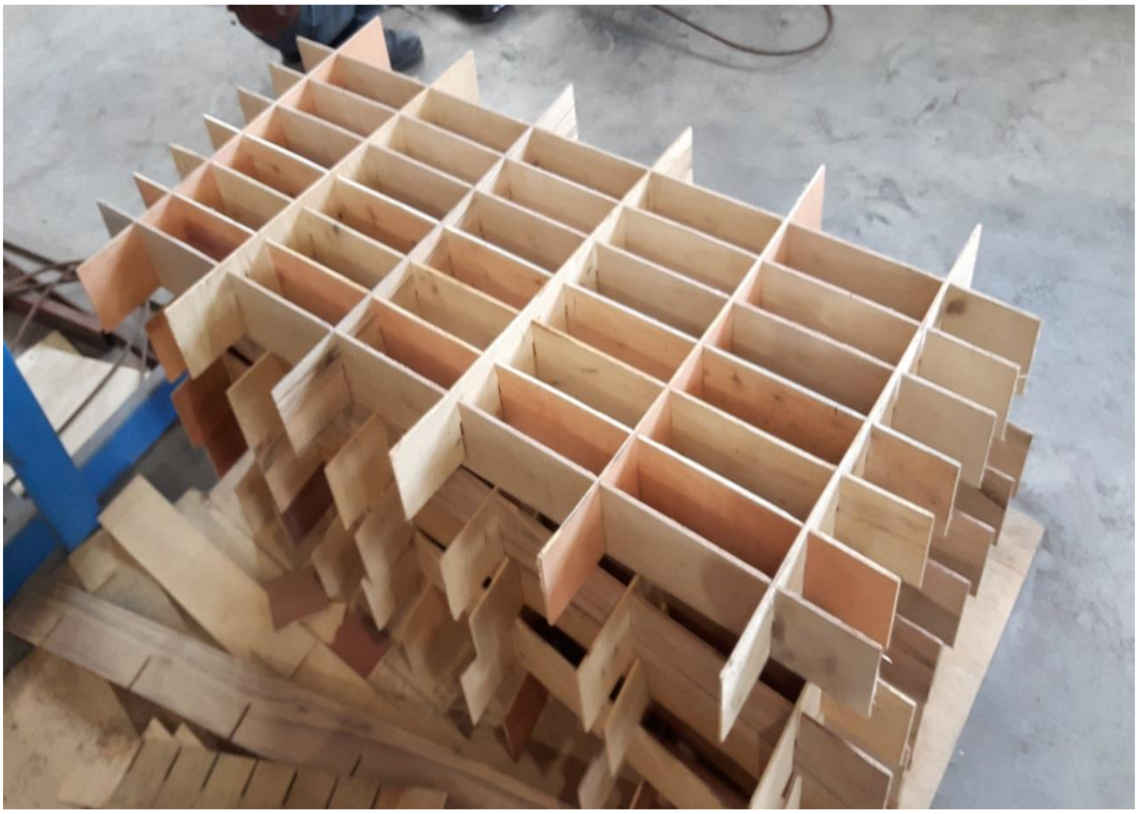
Figure 3.12 Handmade brick mould

Figure 3.13 Unmould brick specimen


Figure 3.14 Brick was cured using air curing

## 3.6 Testing procedure

According to the ASTM standard there are several type of testing for brick. In this study, 3 types of test have been focus which is compressive strength test, flexural strength test and water absorption test. This testing method started with the compressive strength and flexural strength testing once the masonry blocks reached the required age, at the 7,14,28 days and 60 days. Then water absorption rate was obtained at the brick age 28 days.

### 3.6.1 Compressive Strength Test

Compressive strength test was carried out using compressive machine as shown in Figure 3.15. The test was carried out using a Universal Testing Machine (UTM).The test was carried out in UMP concrete laboratory, Faculty of Civil Engineering & Natural Resources according to the standard of compressive strength test ASTM C55 (2011). The compressive strengths of the brick were measured at 7, 14, 28 and 60 days. The apparatus that will be used is Compressive Testing Machine by MATEST. Three samples were prepared for each test. The brick specimens were placed so that the load applied is perpendicular to the surface bed of the masonry block. Then, apply load axially at a uniform rate of 1.25 mm/min till failure occurs and note maximum load at failure. The failure load for the specimen was recorded and all pertinent details regarding the failure were observed. The load at failure is the maximum load at which the sample fails to produce any further increase in the indicator reading on the testing machine. Lastly, the last reading will be taken. Compressive strength of each sample was calculated in MPa ($N/mm^2$). Figure 3.15 shows visuals of the brick under compressive force.

Calculation of compressive strength was done according to the following equation:

$$C=W/\mathrm{A}$$

Where:

C = Compressive Strength, MPa

W = Maximum Load, N indicated by the compression test machine

A = Area of upper and lower bearing surfaces of the sample, $cm^2$


Figure 3.15 Brick under compressive strength test

### 3.6.2 Flexural Strength Test

The flexural strength test was conducted to determine the ability of the specimen to resist the stress. The test was also conducted based on ASTM C55 (2011). The breaking load of the brick at the air curing age 7, 14, 28 and 60 days were obtained. The test was also carried out using the Universal Testing Machine (UTM) where a constant loading rate of 1.27 mm/min was set to the testing machine. The specimen was supported with solid steel rods at the underside while a centre load was applied at the middle point of the brick. The load was applied to the masonry block through a steel bearing plate until the failure of the specimen. The failure load for the specimen was recorded and all pertinent details regarding the failure were observed. The loading must be applied without shock to ensure a much accurate result. Figure 3.16 shows brick undergoes flexural strength testing.

The calculation result were calculated as follows:

$$p = P/w$$

Where :

p = the breaking load per width

P = the transverse breaking load obtained from the machine

w = the width of the masonry

Figure 3.16 Flexural strength testing

### 3.6.3 Water Absorption Test

Moisture absorption rate used to measure the amount of water absorbed under specified condition. This test followed procedures as described in ASTM C55 (2011). Figure 3.17 shows the brick under water absorption. For the water absorption test, the masonry block specimens were weighed and the weight was recorded as $W_{i.}$ The specimen was then dried at 110°C for at least 24 hour in an oven. The weight of the dry specimen was then recorded as $W_d$. After drying, the specimen was cooled in a drying room at 25°C with relative humidity was around 70%. The specimens were then stored to be free from air draft and were un-stacked and separately placed for 4 hour until the surface temperature was approximately 28°C, which was equal to that of the drying room. The specimen was then submerged in clean water at 30°C for 24 hour. The surface water of the specimens was wiped off with a damp cloth and the weights of the specimens were again weighed and recorded as $W_s$ after removing the specimen from the submerged condition. The water absorption of each specimen in percentage was computed as : Calculation

Absorption, % = $100 (W_s – W_d) / W_d$

Where:

$W_d$ = dry weight of the specimen,

$W_s$ = saturated weight of the specimen after submersion in cold water.

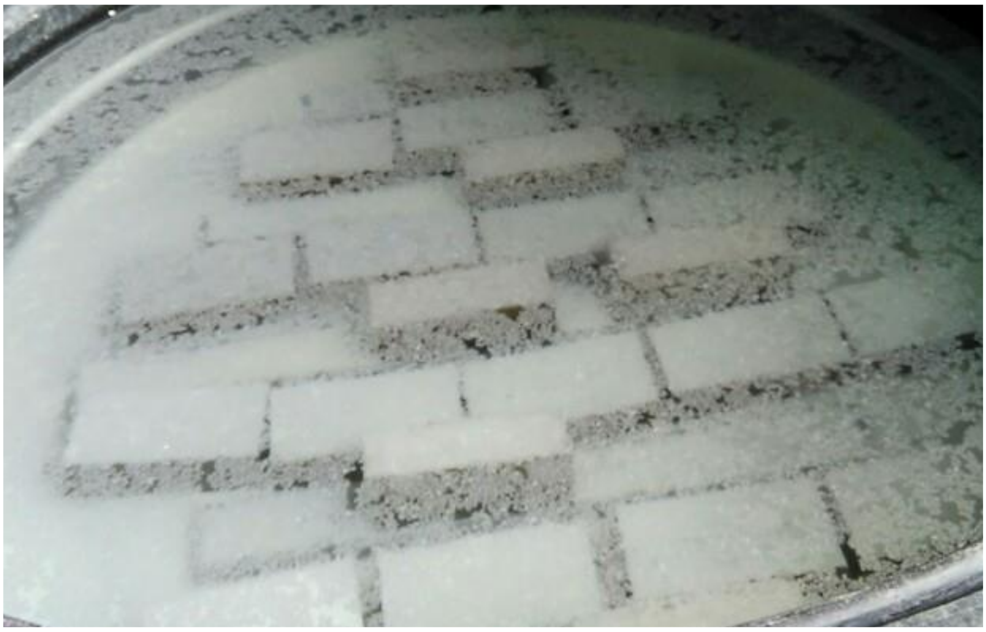

Figure 3.17 Water absorption test

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Introduction

In this research, six mixes were prepared, with one mix for control brick and others five mixes for brick contain various percentages of palm oil fuel ash (POFA). The control sample contains 0% of POFA was casted as common cement sand brick to compare the performance of the brick. In this chapter, the results and discussions of the test is reviewed. The results obtained from the experimental testing had been presented according to the method that has been discussed in the previous chapter. The result of the tests included the mechanical properties tests which are compressive strength test, flexural strength test and water absorption test. A total of 162 bricks were prepared and cured in different curing times for 7, 14, 28 and 60 days.

## 4.2 Compressive strength of cement sand brick

Figure 4.1 show the results on compressive strength of cement sand brick specimens subjected to air curing with 7, 14, 28 and 60 days of curing period. According to the compressive test, the strength recorded at 15% replacement of ground palm oil fuel ash (POFA) shows the highest result of compressive strength. The graphs also indicated that the strength were affected by many factors such as the POFA replacement percentage and the curing age. It can be observed that, the compressive strength of the brick started to increases at replacement percentage of 5% to 15%. While from 20% until 25% replacement the compressive strength of the specimen start to drop.

The logical reason to this is due to particle size of ground POFA was smaller than sand even both of this material was sieve through size 1.18mm. This will make the specimen to become more dense and stronger. However, the replacement percentage has a limit, and in this case, it was from 20% until 25% replacement level. Start from 20% replacement, it can be observed that the strength of the brick decrease with increase in percentage of POFA. The value drop due to increase in porosity of the specimen. Porosity of the specimen increase due to porous structure of POFA particle. Porous structure of POFA will make the structure to become less rigid and less dense. This will lead to a lower strength of the specimen with increased number of POFA inside the specimen. The strength of specimen contain 20% of POFA lower than specimen contain 5% POFA, it strength cannot be accepted because the specimen has a lower strength compare to control specimen.

Table 4.1 Result of compresive strength

| **Percentage Ground POFA (%)** | **Compresive Strength (MPa)** | | | |
|---|---|---|---|---|
| | **7 days** | **14 days** | **28 days** | **60 days** |
| 0% | 6.02 | 7.28 | 8.08 | 8.44 |
| 5% | 8.26 | 9.55 | 10.85 | 11.14 |
| 10% | 9.64 | 9.87 | 13.28 | 13.50 |
| 15% | 11.31 | 14.29 | 16.19 | 17.02 |
| 20% | 4.55 | 7.50 | 7.84 | 10.01 |
| 25% | 6.20 | 7.60 | 7.63 | 7.15 |

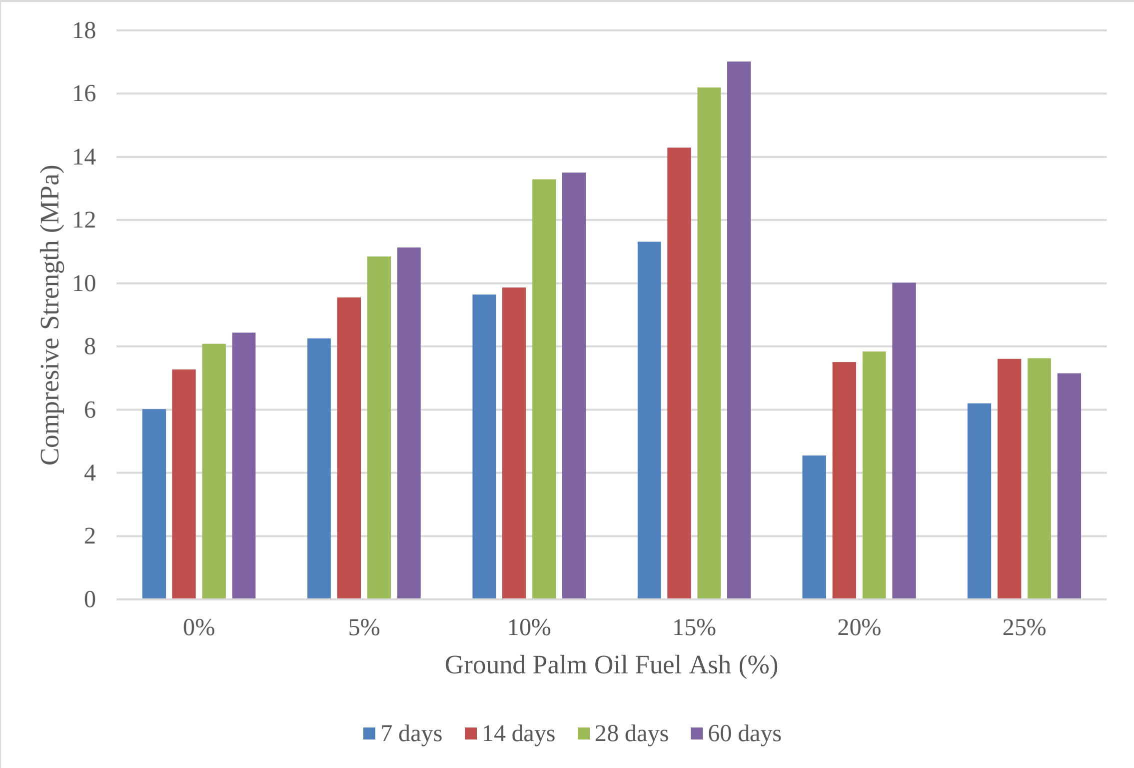


Figure 4.1 Compressive strength at 7, 14, 28 and 60 days

### 4.3 Flexural strength of cement sand brick

Figure 4.2 show the results on compressive strength of cement sand brick with respect to 7, 14, 28 and 60 days of curing period. In this section, the flexural tests conducted on the samples are presented. The average reading from the flexural test results of three samples of each type of samples are taken to increase the accuracy of the reading. Six types of samples were prepared, just like the compressive strength tests, the samples are the control samples with no POFA and five other samples which contain 0%, 5%, 10%, 15%, 20% and 25% of ground POFA. The samples were casted and label then went through 7, 14, 28 and 60 days of water curing before being tested. The result indicates that, specimen containing 15% of palm oil fuel ash (POFA) has the highest flexural strength.

The result for flexural strength is almost similar to the compressive strength. The brick started to increase at early replacement until replacement percentage of 15%, while from 20% to 25% replacement, the flexural strength of the specimen start to drop. For flexural strength, only replacement percentage of 15% show a higher result compare to plain specimen. The highest flexural strength was recorded at 60 days of curing age for 15% POFA replacement. The strength was 0.401 (MPa). The strength of the specimen increase due to ability of POFA to fill the void inside the specimen. In general, POFA particle size is smaller than particle size of sand. So, at certain amount of replacement in this case which is 15%, the POFA particle can fill the void inside the specimen. This will cause the specimen to become more dense and stronger.

Table 4.2 Result of flexural strength

| Percentage Ground POFA (%) | Flexural Strength (MPa) | | | |
|---|---|---|---|---|
| | 7 days | 14 days | 28 days | 60 days |
| 0% | 0.242 | 0.214 | 0.301 | 0.340 |
| 5% | 0.246 | 0.263 | 0.329 | 0.344 |
| 10% | 0.266 | 0.261 | 0.325 | 0.399 |
| 15% | 0.242 | 0.315 | 0.318 | 0.401 |
| 20% | 0.169 | 0.209 | 0.223 | 0.257 |
| 25% | 0.157 | 0.154 | 0.198 | 0.258 |

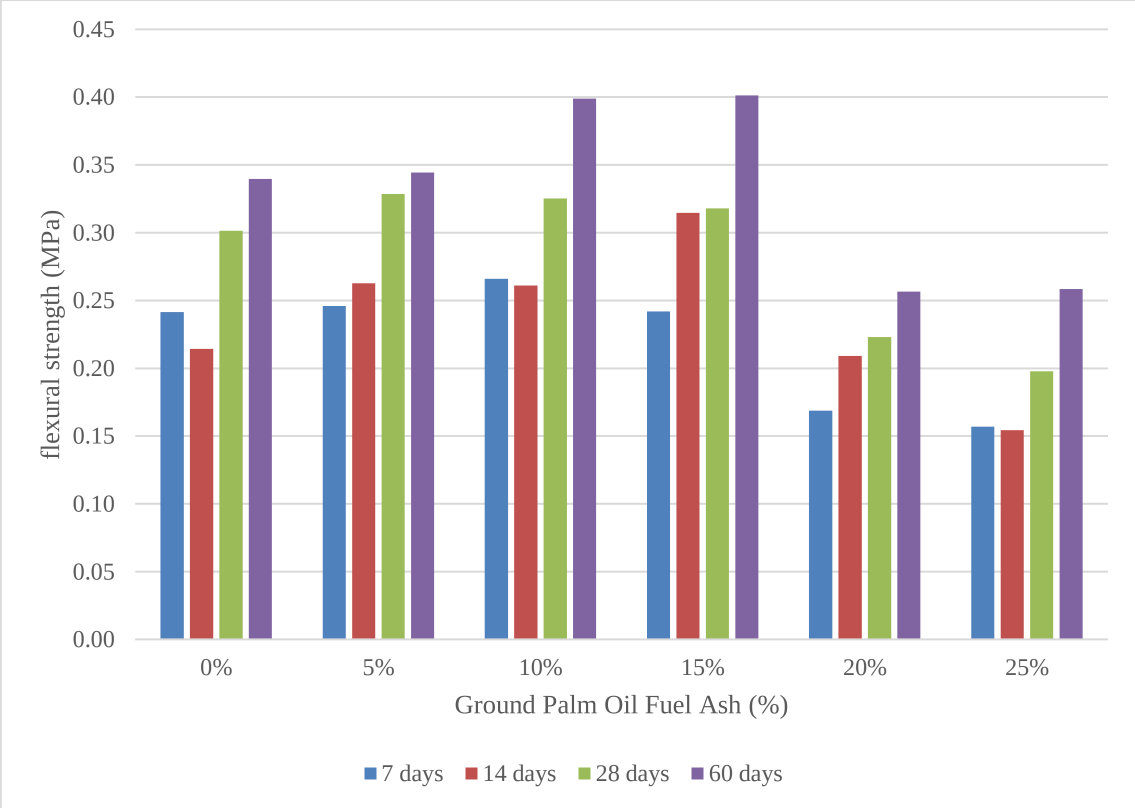


Figure 4.2 Flexural strength at 7, 14, 28 and 60 days

### 4.4 Water absorption of cement sand brick

Water absorption test is used to test the ability of the bricks to absorb water at specific time. According to Castro et al. (2011), the water absorption test is an important laboratory analysis or important factor in determining the durability of cementitious systems. This test is only conducted on concrete of 28 days. The result of rate of water absorption of the bricks with different percentages of ground POFA is tabulated in Table 4.3. In general, bricks are considered as unsuitable when they have high percentage of water absorption. In this section, the results on water absorption of cement sand brick are presented.

Based on the result, water absorption starting to decreases from replacement percentage of 5%. While from 20% until 25% replacement, the water absorption of the specimen start to increase. The results show that the sample containing 15% POFA had the lowest water absorption compared to that of the other mixes. The water absorption percentage for the 28 days of air curing age is 5.96%. The use of adequate POFA would reduce the water absorption of cement sand brick. POFA is functioned as filler to fill the void in the brick, making the brick much denser. Thus, the brick void could be reduced and the brick would absorb less water. It can be said that the size and the chemical composition of POFA would influence the density, strength and water absorption.

Table 4.3 Result for water absorption

| POFA Percentage (%) | Water Absorption Percentage (%) For age 28 days |
|---|---|
| 0% | 8.780 |
| 5% | 9.211 |
| 10% | 6.949 |
| 15% | 5.961 |
| 20% | 13.021 |
| 25% | 15.209 |

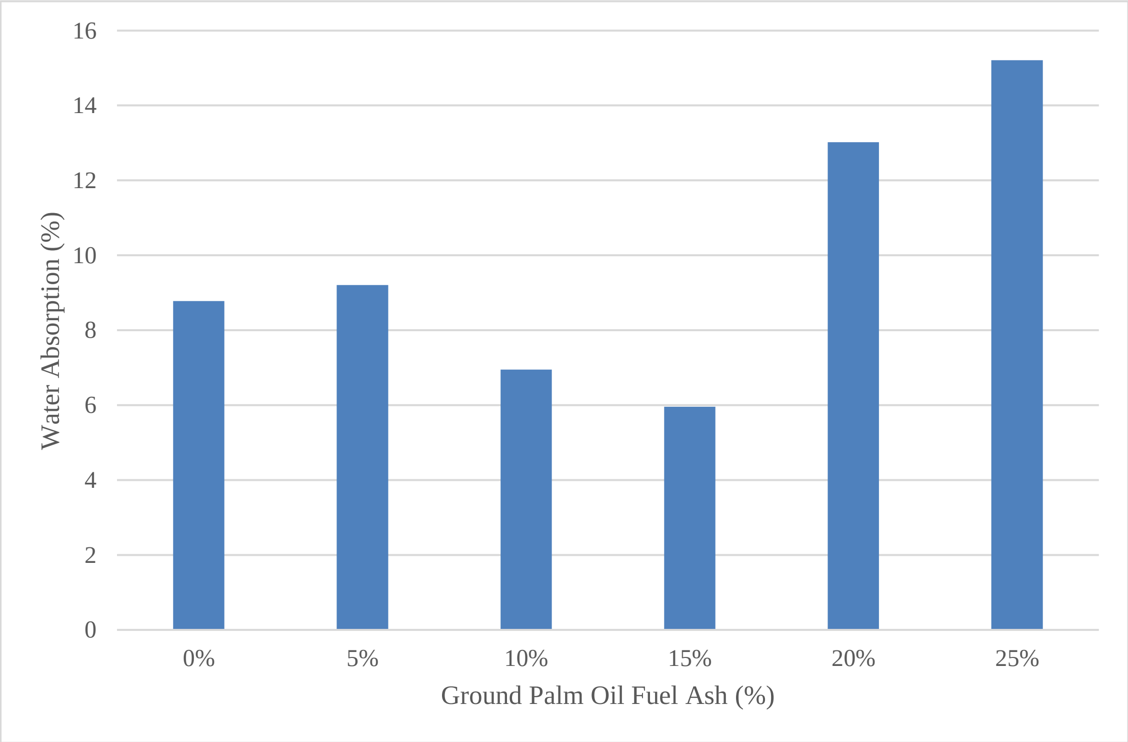


Figure 4.3 Water absorption test result

### 4.5 Discussion

Based on result from the testing of compressive strength, flexural strength, and water absorption. Ground POFA seems to have a good potential for cement replacement in cement sand production. Based on previous research from (Sata, 2004) It was found that high-strength concrete can be achieved by using ground POFA to replace portland cement Type I up to 30%. Concrete with 20% replacement of ground POFA had the highest strength. In this research, the trend of the compresive strength is almost similar with the previous finding. But for this research, the optimom content for ground POFA replacement is 15%. Previous finding from (Deepak, 2014) on flexural strength, it was found that cement with 15% replacement of POFA had flexural strength slightly higher than OPC alone. For the result on the brick flexural strength in this research also has similar trend where the highest strength is 15% replacement. By using POFA and concrete and brick fillers, the construction industry moves closer to achieving sustainability. Results of research studies show the validity of this approach and the potential for further successes in sustainability using POFA, together in concrete mixtures, as partial cement and sand replacement.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Introduction

This chapter presents the conclusion of this research based on the objectives which have been set at the beginning stage of the research. The objectives of this research is to study the mechanical properties of cement sand brick containing ground palm oil fuel ash (POFA) as partial sand replacement in term of compressive strength, flexural strength and water absorption. 6 mixes had has been use to replace sand in different percentage of ground POFA which is 0%, 5%, 10%, 15% and 20%, and 25%.

## 5.2 Conclusion

This research had demonstrated the utilization palm oil fuel ash as partial sand replacement for cement sand brick. From the results and discussions made, it can be concluded that the objectives of this study were achieved. Based on the analysis and result in Chapter 4, several conclusions can be drawn:

i. With regard to compressive strength, brick produced from 15% POFA as partial sand replacement display that the highest strength compared to plain cement-sand brick because POFA particles are smaller than river sand particle. Therefore, POFA particle would act as filler effect to fill the void inside the brick and make the brick to become more dense and stronger.
ii. In term of flexural strength, brick containing 15% of POFA shows the highest flexural strength. This probably due to small particle size of POC compare to natural river sand which can fill the void inside the brick thus make the brick more dense and stronger.

iii. The present of POFA in brick would affect the water absorption percentage. Brick containing 15% POFA show that value of water absorption is the lowest compare to plain cement sand brick.

## 5.3 Recommendation

There are several recommendation that had been identified for future development of ground palm oil fuel ash (POFA) as a replacing material in brick industry. Hence, the following recommendations are:

i) Investigate performance of brick with POFA under different curing method

ii) Study on the durability of cement sand brick such as chemical attack resistance, fire resistance and thermal conductivity.

iii) Determine the performance of brick containing POFA in real world application such as effect of the brick from the change of natural weather and environment for at least one year.

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